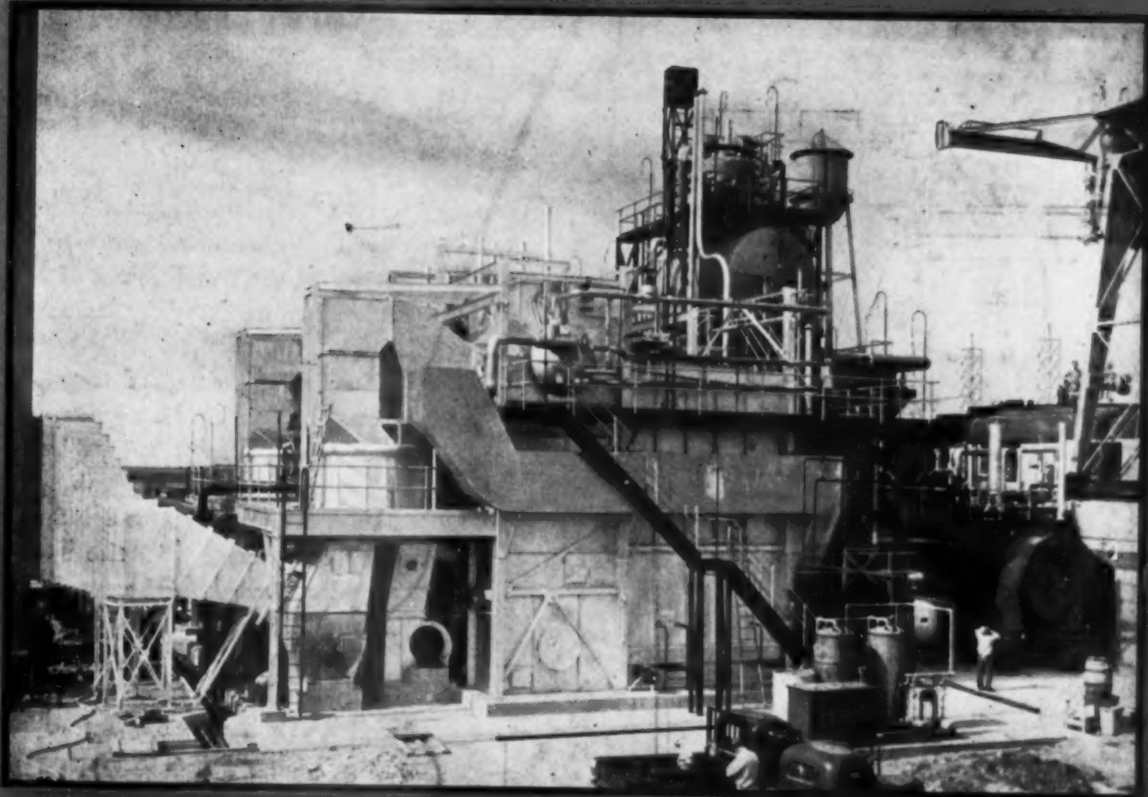
COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

January, 1949



A recent outdoor installation in Texas

The New O. H. Hutchings Station

Survey Shows Power Situation

Deposit Formations on Boiler Tubes

COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

VOLUME TWENTY NUMBER SEVEN

CONTENTS

FOR JANUARY 1949

FEATURE ARTICLES

EDITORIALS

DEPARTMENTS

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EDITORIAL

Professional Registration

Inasmuch as all forty-eight states have enacted laws requiring the licensing of practicing engineers, it is evident that matters pertaining to such professional registration are of more than passing interest.

Dr. A. M. Sargent, a registered professional engineer, in a stimulating short book entitled "Professional Registration Laws and the Engineer," has raised certain pertinent questions which, although long recognized by some, have heretofore received little general attention. They deal, in part, with the difficulty of specifically defining engineering; with doubtful protection to the public through licensing when an all-inclusive license is issued to cover innumerable branches of the field; to lack of uniformity among the state laws; and to ineffectual enforcement in many states because of uncertainties in the laws.

"The laws," he says, "have failed to recognize that engineering is one of the most highly specialized professions. They have created a mythical classification of *professional engineer*, and, according to the legal language of many of the laws, such a man is a specialist in the field of engineering as a whole, competent in all branches."

The question has often been raised as to the impossibility of applying any single examination yardstick for judging applicants in widely diversified fields, such, for instance, as power plant design and ceramic engineering. Yet, hypothetically, two engineers of such widely different backgrounds might pass the required examination and, under the laws of some states, have the legal right to practice as professional engineers in one another's fields.

Many similar examples might be cited, but this is true not alone of engineering. There are as many branches in medicine and surgery, and the reasoning also applies to law.

Obviously, it would be a mistake to regard professional registration as a guarantee of competency, any more than it would be so to regard a physician's or a lawyer's license to practice; it merely shows that the holder has successfully met certain fundamental and minimum technical requirements.

Notwithstanding the foregoing, professional engineering registration has made remarkable strides; and whether this be due, as Dr. Sargent claims, to pressure by engineers rather than public demand for protection, it is here to stay. There are now over 130,000 registered professional engineers throughout the United States, exclusive of land surveyors; and the National Society of Professional Engineers reports a membership of some nineteen thousand. Moreover, efforts are continually being directed toward improvement in the laws, in their enforcement, and toward greater standardization to permit more widespread reciprocity between states—a work in which the National Council of State Boards of Engineering Examiners has long been active.

While a book such as that by Dr. Sargent serves a very useful purpose in stimulating constructive thinking on the subject, it cannot be denied that registration has been a most important factor in raising the prestige of the engineering profession.

Capacity Outlook Improves

Continued increase in electrical demand throughout the country of more than ten per cent per year, with no indications of letup in the foreseeable future, has been responsible for predictions of critical power shortages in certain areas. However, although the margin of reserve capacity is still inadequate, it is steadily being improved and is expected to reach a substantial figure by next year.

The report of the Second National Electric Power Survey to the National Security Resources Board, which is briefed elsewhere in this issue, represents the latest and most comprehensive information at present obtainable on the subject. Issued in December 1948, it is the result of the cooperative efforts of government power agencies, the electric utility industry, and suppliers of power generating equipment.

New capacity installed in 1948 more than met expectations and will be exceeded by shipments scheduled for 1949 and for 1950. In fact, the four-year period of 1948 through 1951 includes scheduled shipments of nearly twenty-four million kilowatts of which about eighty-seven per cent applies to electric utilities. Steam accounts for at least seventy-five per cent of the new privately owned utility capacity.

Turbine manufacturing facilities for building large units, as great as they are, appear to be the present limiting factor and are well taken up for the next two years, although considerable open capacity is available for the building of turbines of 10,000 kw and under. On the other hand, manufacturing facilities for steam generating units present no problem.

Viewing the situation broadly, and despite existing close margins, it is believed that efforts of equipment suppliers together with the resourcefulness of the utilities can be depended upon to ease any serious shortages that may arise. Meanwhile the outlook continues to improve month by month.

Aerial view of station from electrical end

The New O. H. Hutchings Station

This station has been designed for an ultimate capacity of 360,000 kw of which one 60,000-kw turbine-generator and two 500,000-lb per hr boilers are now in operation. Steam conditions are 1350 psig, 950 F and the boiler room is of the semi-outdoor type. Operating results from July 6 to December 28, 1948 are given.

By R. D. GILLESPIE

Manager, Power Production Div.
The Dayton Power and Light Co.

ON JULY 12, 1948, the first 60,000-kw unit of the new O. H. Hutchings Electric Generating Station of The Dayton Power and Light Company, near Miamisburg, Ohio, formally went on the line. This was almost 19 months to the day between the time ground was broken for the station and the time the first unit was placed in service.

This new station has a projected ultimate capacity of 360,000 kw which will be one and one-half times the present capacity of the Frank M. Tait Station, up to now the single source of electric generation for the Company.

The first 60,000-kw unit of the O. H. Hutchings Station represents an investment of more than $15,000,000. This figure includes the cost of the generating unit now in service and the principal facilities necessary to serve it and the other five units which are projected for installation.

When the present Frank M. Tait Station, located three miles south of Dayton, was placed in operation in March of 1918, with a total capacity of 25,000 kw in two units it was believed that the site could be developed to an ultimate 100,000-kw capacity. During the ten-year period from 1918 to 1928 the system load had increased at such a rapid rate that it became necessary to install an additional 85,000 kw of new capacity which brought the total generating capacity of the station up to 110,000 kw.

During the latter part of 1935 the system load had increased to the extent that it became necessary to plan for additional generating capacity. This was accomplished by installing our first 30,000-kw, 1200-psi, hydrogen-cooled topping unit, supplied by two 375,000-lb per hr boilers, placed in operation in 1937.

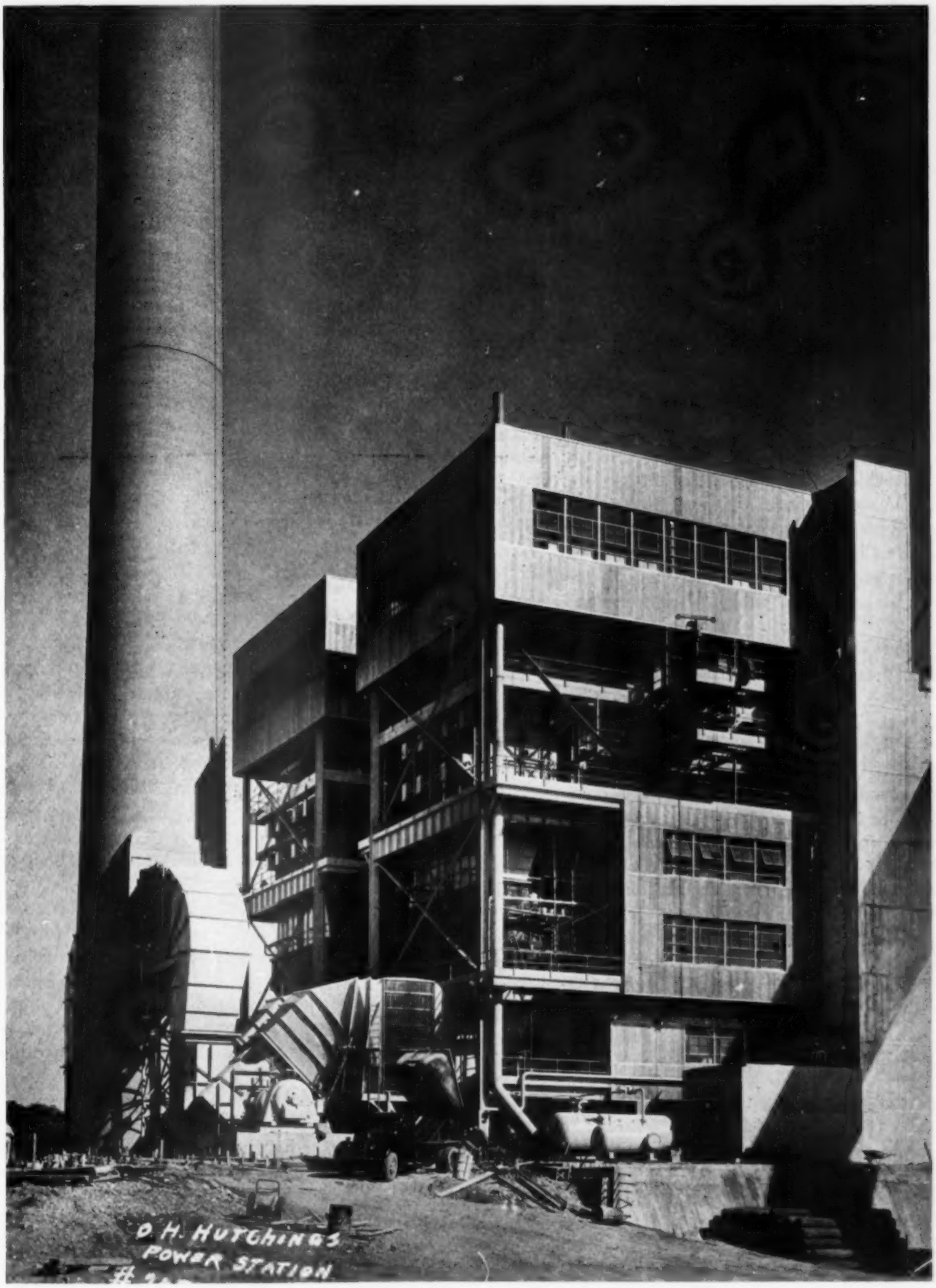
Between the years 1937 and 1944 an additional 30,000-kw, hydrogen-cooled topping unit was installed together with two high-pressure boilers, and the two original 12,500-kw units which had been in operation for 25 years were replaced with two 30,000-kw, hydrogen-cooled, low-pressure units.

With these additions and replacements the total generating capacity of the Frank M. Tait Station is now 210,000 kw, with eight units installed.

During the war years a study of the system load and the rate of increase of new electrical business indicated that by the spring of 1949 an additional 100,000 kw of generating capacity would be required to keep abreast of the system growth and the increasing demand for electric service in the territory served by the Company.

There were two principal means of increasing system capacity. The present station could be topped out and some of the present low-pressure turbines replaced with larger units; or a new station could be built. The first alternative would net only some 60,000 kw of additional capacity and would involve outages of equipment, which could not be tolerated at a time when electric demand was steadily increasing.

These considerations led to the decision to construct a new electric generating station, the O. H. Hutchings



View of boiler room showing semi-outdoor construction

Station, some ten miles south of Dayton, Ohio, on the west bank of the Great Miami River.

Site Considerations

The site selected adequately fulfills the following requirements:

1. An adequate supply of condensing water.
2. Facilities for the receipt and storage of coal: The new station is immediately adjacent to the main line of one of the several railroads which serves the area, on a site sufficiently large to store an adequate supply of coal.
3. Nearness to load area to be served: Geographically the new station is in a very favorable situation to serve efficiently the entire territory of the Company.
4. Adequate supply of well water: The subterranean strata are very favorable, assuring an abundant supply of well water for many years to come.
5. Protection against flood: By the flood control program of the Miami Conservancy District, the waters of the Great Miami River are held in check by dry reservoirs situated at strategic points in its tributaries. Notwithstanding the effectiveness of the program, the river bed adjacent to the station site was dredged to a greater width and depth, and suitable earthen dikes erected to direct the flow. The general level of the site was established 1.5 ft above extreme flood level, and the operating floor was placed 13 ft above grade.
6. Ash disposal: In a solid fuel burning plant, the problem of ash disposal is of considerable importance. A solution to this problem was satisfactorily provided by virtue of the excavations adjacent to the plant, from which were obtained the gravel and sand necessary for the concrete utilized in the structure. As the craters for gravel needs grew there were fortuitously created disposal areas for ashes and other debris for many years to come.

Foundation work of the station itself required the construction of a coffer dam 500 ft long and 54 ft wide, which consisted of circular coffers, 18 ft in diameter and 40 ft between centers, connected by steel-piling diaphragms. This unusual type of construction saves an appreciable amount of steel by eliminating the cross members normally required to give the dam rigidity. It also permits the use of drag-line excavation over the entire length in place of the less efficient clam-shell.

The station is erected on a re-enforced concrete mat, the alluvium affording a firm foundation for the structure and making piling unnecessary. All heavy equipment is carried on concrete footings designed not only to provide a solid foundation but also for accessibility and ease in maintenance. The building is of steel frame construction, faced with Indiana limestone and face brick

Coal-Handling System

Coal is received by rail and shifted by a diesel-electric locomotive. It is unloaded by means of a car dumper of 100-ton capacity, and transported from two 200-ton hoppers by apron feeders to a 700-ton per hr conveyor belt. These apron feeders also serve two 100-ton track or reclaiming hoppers.

The conveyor belt terminates at a crusher house where all or part of the coal may be discharged to storage, or crushed and sent to bunkers. The crusher may be bypassed when coal of correct size is available. Storage and reclaiming are accomplished by means of a 20-ton tractor which may be used as a bulldozer or as the prime mover for a 25-cu yd carryall. The conveyor belt from crusher house to the transfer tower has a capacity of 350 tons per hour. At the transfer tower the coal discharges past an automatic sampler to the horizontal conveyor.

Satisfactory experience with the conveyors at the existing station precluded the need for duplicates. The conveyor housing was kept to a minimum by providing a walk on only one side of the conveyor from which all lubrication is performed. It has a concrete roof and floor, and transite siding, with no windows.

A sealed, parabolic bunker of suspended steel construction, having a capacity of 600 tons per boiler, is maintained under a slight suction for dust control. Two coal chutes with sliding gates transport the coal to the weighting-scale hopper of each mill.

Steam Generating Units

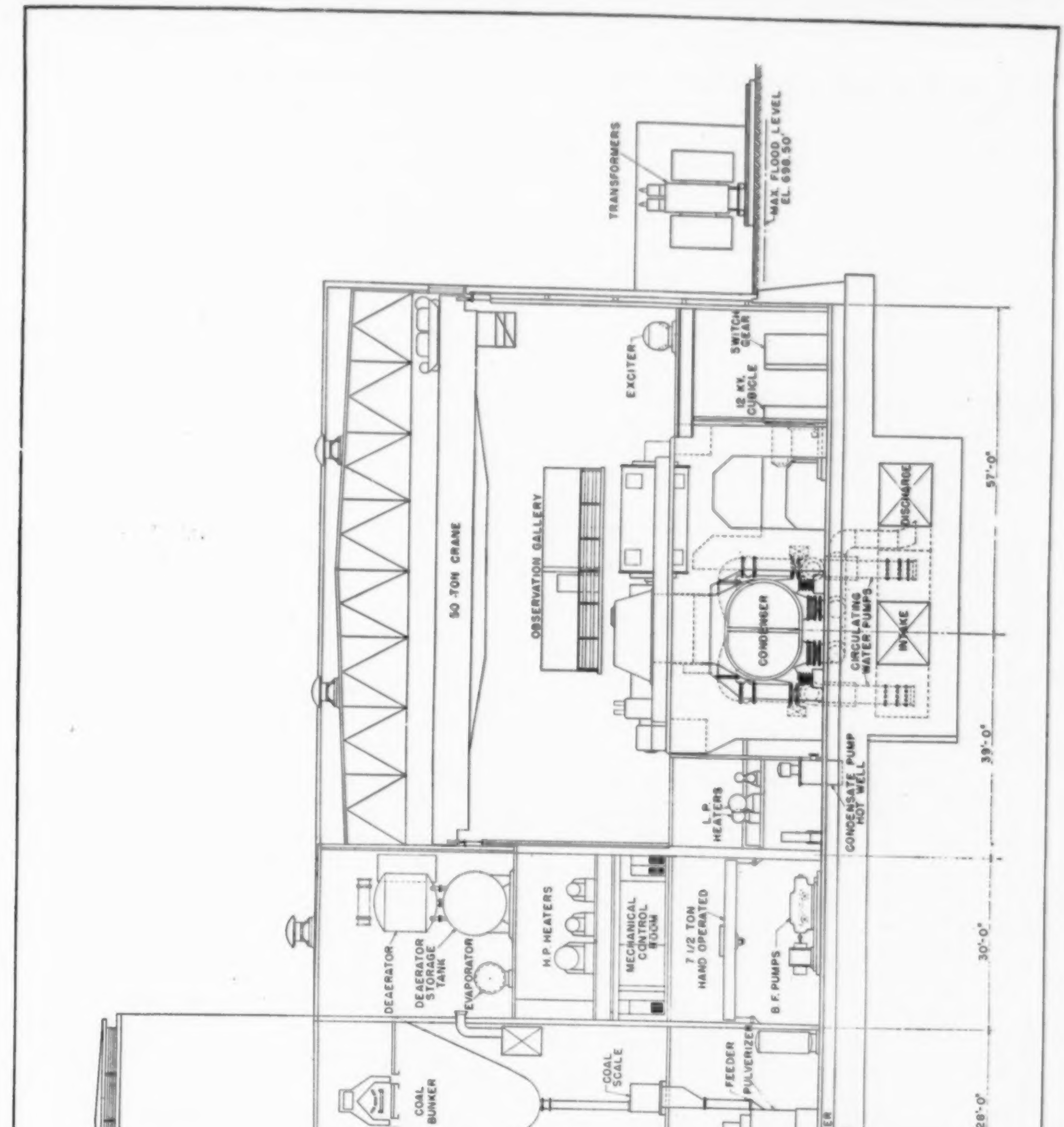
The boilers are of the semi-outdoor type which is unusual for this part of the country because of climatic conditions. Insulated aluminum panels are used to enclose the boilers at the burner and drum levels. The air heaters, dust collectors and induced-draft fans are out of doors, whereas the motors and hydraulic couplings on the induced-draft fans are enclosed. All breeching and duct work is either lined with gunite or covered with weatherproof insulation. Uninsulated equipment located out of doors includes a cold condensate tank and air compressor receivers.

Three 9-ton per hr bowl mills supply coal to each boiler. Tangential firing, with tilting burners, produces a continuous output of 500,000 lb per hr or 550,000 lb per hr for 12 hr. Primary and secondary pendant-type superheaters supply steam at 950 F. The superheat temperature is regulated primarily by tilting the burners automatically and secondarily by the bypass damper.

The fin-tube economizer is located between the boiler exit and the entrance to the two regenerative-type air heaters. Following the air heaters is a multiple-cyclone dust collector and the induced-draft fan. The latter discharges into a 250-ft radial brick stack. The stack which serves two boilers, is built on the ground. An inner stack of red brick, 14 ft in diameter, is so constructed as to leave an annular space between the two courses. With a double cap arrangement it is believed that a build-up of fly ash on the top of the stack can be prevented. Provision has been made for the installation of aircraft warning lights if required at some future time.

The forced-draft fan is located in the basement. It receives air from the building in summer and from the outside in winter. During the latter period tempering air from the air heater discharge is used to minimize air heater corrosion. Air flow regulation is by vane control.

Ash from the dry, basket-bottom furnace falls into a water-filled pit from which it is sluiced to an ash sump. It is pumped from that point to an old gravel pit adjacent to the station. When this has been filled, additional space will be available about 500 ft from the station in the gravel pit previously mentioned. The same system is used to handle fly ash from the dust collectors, the base of the stack and hoppers on the boilers. This ash is delivered to the sump by means of a hydraulic vacuum system.



Cross-section through boiler and turbine room

Although the station is of the unit type, No. 1 turbine will be supplied by either No. 1 or No. 2 boiler until such time as No. 2 turbine is ready for operation. During the interval, each boiler is equipped with two stop valves instead of a stop valve and a non-return valve. The additional stop valve on each boiler will be removed when the interconnection between the two boilers is eliminated. These stop valves are 10 in., installed in 12-in. steam lines.

Turbine-Generator

The turbine is of conventional design with throttle conditions of 950 F and 1250 psig. It has six high-pressure, eleven intermediate, and four low-pressure, double-flow stages, and drives a 70,588-kva, 3600-rpm, hydrogen-cooled generator.

Two 21,600-gpm vertical circulating pumps supply a two-pass radial condenser without divided water boxes. One pump will be sufficient except during periods of high river temperature. A two-stage steam jet air ejector is provided. Building height was reduced by placing the condenser hotwell close to the floor and connecting it to two sumps from which the condensate is removed by vertical pumps.

The extraction heater arrangement is shown on the heat balance. In this connection, it may be said that ease of maintenance influenced the choice of the U-tube type of closed heater. This is a departure from the floating-head type now in use at the Tait Station.

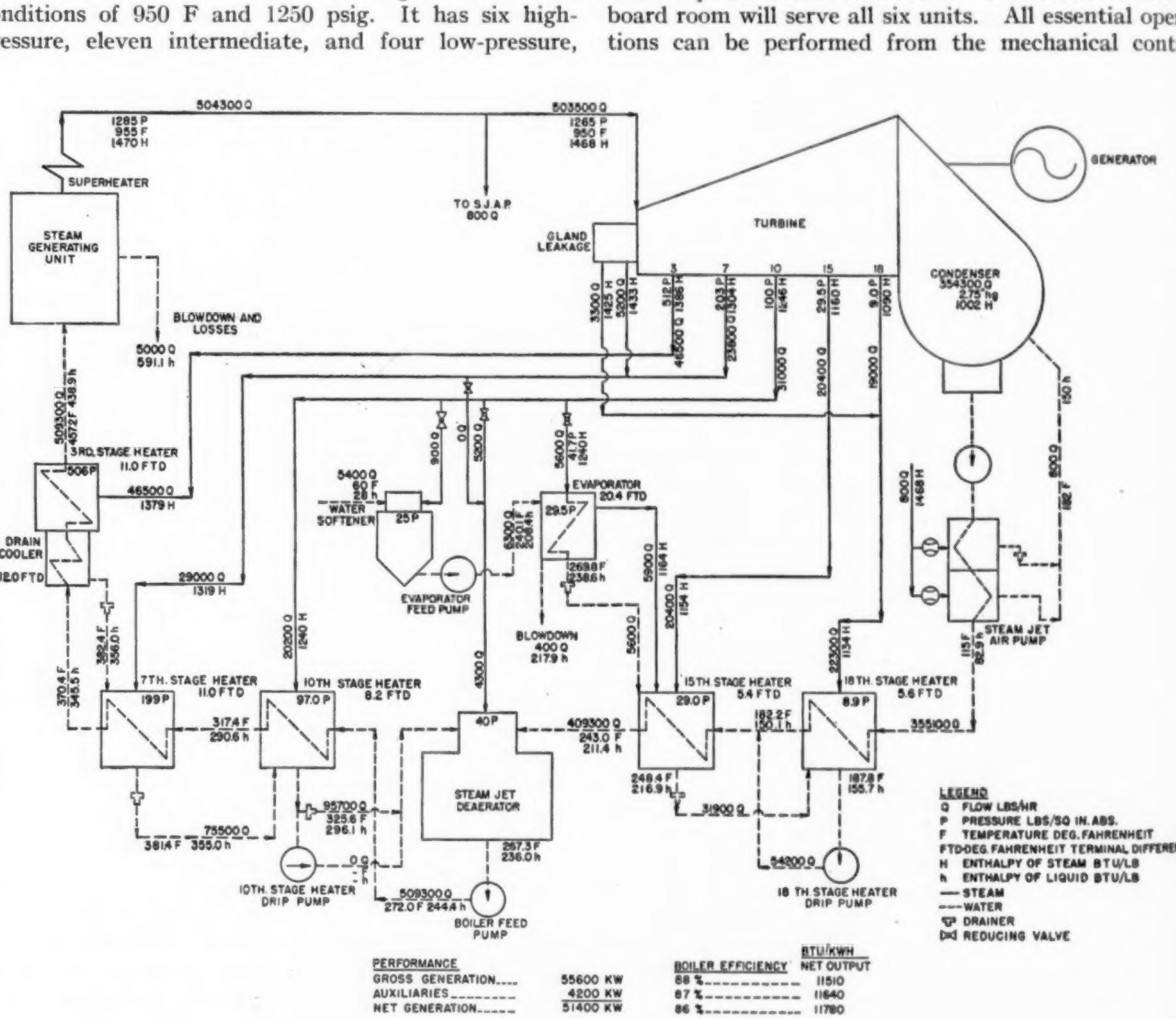
A spray-type deaerating heater was employed to minimize internal boiler corrosion. It was not believed that deaerating-type hotwells could do this job effectively.

Controls and Operating Staff

Considerable operating economies are expected from the use of a central mechanical control room. Two units will be operated from each room. One electrical switchboard room will serve all six units. All essential operations can be performed from the mechanical control room except starting of the turbine, circulating pumps and well water pumps, and operation of the screens and ash removal system.

Each shift will have two men in the control room, and one auxiliary operator and one apprentice operator outside the control room. These four men will staff two units. Also, there will be one switchboard operator and one shift engineer for the entire station. Thus for each two units that are added, only four additional operators will be needed per shift.

An adequate supply of condensing water is assured by the erection of an 8-ft dam across the Miami River ad-



Heat balance diagram

jacent to the station. This dam is equipped with a gate structure, which may be raised or lowered for recirculation or discharge of excess water. The pool is 1500 ft in length, between discharge gates and station water intake bay.

Two gas-fired boilers provide steam for unit heaters located in the shops, screen house, storerooms, etc. During warm weather, air is brought in from the roof. It is filtered through oil-bath screens and carried through ducts to discharge points in the turbine room, boiler room, basement, machine shop, storerooms, etc. From there it finds its way back to the inlet of the forced-draft fan in the basement. The offices are air conditioned.

Adjacent to the new station, a substation was erected to handle the 12,500-volt output of the generating station and by means of transformers to step up the voltage to 66,000 volts for transmission over four circuits to the present system 66,000-volt transmission ring. Each circuit is provided with fault-bus protection and high-speed carrier pilot relays. Oil circuit-breakers for each outgoing circuit are of 2,500,000 kva interrupting capacity.

A total of 32.5 miles of new 66,000-volt transmission lines were erected to tie in the output of the new Hutchings Station with existing transmission facilities out of the present Frank M. Tait Station. This new portion of the transmission system carries 636,000-circular mil ACSR conductors. An existing 8.5 miles of 437,000-circular mil ACSR transmission service are being replaced with conductors of 636,000-circular mil ACSR. All in all, a total of 41 miles of new lines will be erected to provide another loop in the company's present transmission system.

The normal auxiliary power supply will be through a 6000-kva, 12,500-volt to 2300-volt unit transformer. An alternate supply is provided through a 7500-kva, 66,000-volt to 2300-volt station transformer. Both are located outdoors.

Notes on Operation
(*July 6, 1948, to December 28, 1948*)

No. 1 unit was placed in service for the first time on July 6—nineteen months after ground was broken for the building. The ash removal system was operated on hand control as were the boiler feedwater, combustion and superheat controls.

The load on the unit was increased gradually until by July 8 it was generating 55,000 kw. On July 12 the formal ceremonies dedicating the station were held.

The events leading up to the initial operation were uneventful. The boiler was acid-cleaned before placing it in service. The boil-out, setting of the safety valves and the turbine heat run were all accomplished, using the ignition gas on the boiler as fuel. Only the usual leaks in the tube rolls on the boiler were encountered. No difficulty was experienced with the turbine or generator.

The automatic feedwater control was placed in service soon after the unit went on the line and the combustion and superheat controls were placed in automatic operation within a month. The latter uses the tilting burners for primary control and the bypass damper for secondary control.

The superheat control has been quite effective. It regulates within ±10 deg at 950 F and has been generally trouble free. Several of the Woodruff keys in the driving mechanism of the burner tilts have sheared.

The automatic sequential air soot-blowing system has proved to be effective. The boiler has been free of ash and slag with the exception of a narrow band of slag immediately above the burners. This has caused no difficulty, but wall blowers were added later to remove it if necessary.

This unit is base loaded whenever possible, having a load factor of 90 per cent or higher. During the months of October, November and December its net heat rate averaged approximately 10,800 Btu per kwhr, with a net coal rate of 0.82 lb per kwhr.

No accurate figures are available on the boiler efficiency due to the fact that the first extraction heater is not in service. When an attempt was made to increase the load on the unit above 64,000 kw, the extraction pressure exceeded the design pressure on the third stage heater shell. So far, this has limited the load on the unit to this amount. A new shell will soon be installed on this heater.

There were eight forced outages on the unit during the first six months of operation. Five of these were due to human errors, of which four were caused directly or indirectly by contractor's men tripping the unit off the line electrically. An improper setting of a differential relay caused one outage and the other two were the result of leaks in the economizer. These leaks apparently developed from slag occlusions in the forged welds of the return bends. They were relatively simple to repair, but considerable time was lost in cleaning the wet ash out of the air heater and dust collector.

As this article is written we are experiencing our first cold weather (+7 F). Moisture in the air to the soot-blower operating mechanism and the control air to the valves on the dust collector hoppers has been the only source of trouble so far in this our first experience with a semi-outdoor installation north of the Mason-Dixon Line.

FORCED OUTAGES

		Time Off Hr.	Time Off Min.
July 8	Differential relay on C phase of generator bank of transformers tripped unit off. Improper setting	..	15
July 20	Contractor's men working on control wiring for No. 2 unit, tripped No. 1 unit off	..	39
July 24	Pulverizer mills puffed out due to inexperience of the operators	1	10
Aug. 16	Electricians working in auxiliary power board tripped auxiliaries off, forcing a shutdown of unit	..	30
Aug. 23	Faulty contactor transferred unit's auxiliaries to No. 2 unit. Not aware of this, electrician cleared No. 2 unit power board for maintenance and shutdown unit	2	15
Aug. 31	Small hole opened in end of return bend of an economizer tube	24	47
Sept. 11	Small hole opened in end of return bend of an economizer tube	32	10
Nov. 28	Tarpaulin used by construction men was carried by high wind into main and auxiliary transformer banks, tripping both main unit and all auxiliaries	5	11
Total		66	57

Total hours (July 6–December 27) = 4182
Hours unit available = 4115
Percent of time available = 98.4

PRINCIPAL EQUIPMENT—O. H. HUTCHINGS STATION, THE DAYTON POWER AND LIGHT COMPANY

STEAM GENERATING EQUIPMENT

Steam Generating Units

Combustion Engineering, 3-drum type, 500,000 lb per hr continuous, 550,000 lb per hr for 12 hr. Operating pressure 1350 psig at S.O.; design pressure 1500 psig. Heating surface: boiler 6600 sq ft, furnace walls 9,510 sq ft. Furnace data: width 24 ft-$2^{3}/_{8}$ in., depth 21 ft-4 in., volume 34,000 cu ft gross; liberation 18,800 Btu per cu ft. Tubes: roof, fin; front, sides and rear plain.

Elesco, two-stage interbank (split), pendant type superheater; steam temperature at outlet 950 F; range 220,000 to 550,000 lb per hr. Temperature control: primary, tilting burners; secondary, bypass damper, both automatically controlled. Heating surface 16,537 sq ft.

Twelve Type TV burners per boiler, corner mounted for tangential firing; tilting ±30 deg; provision for burning gas.

Pulverizer Mills

C. E. Raymond bowl mills, three per boiler, 9 tons each.

Coal Scales

Stock Engineering Co., 18 tons per hr, 400-lb hopper.

Air Preheaters

Air Preheater Corp., Ljungstrom regenerative type; two per boiler; heating surface 43,180 sq ft.

Forced-Draft Fan

B. F. Sturtevant Division, Westinghouse. One per boiler; horizontal, double inlet. Control, inlet vanes and outlet damper; capacity 154,000 cfm at 80 F, 12.3 in. water. Drive, a-c, 400-hp, 2300-v, constant-speed motor.

Induced-Draft Fan

B. F. Sturtevant Division, Westinghouse. One per boiler; horizontal, double inlet. Control, hydraulic coupling and inlet damper; capacity 267,000 cfm at 308 F, 19.86 in. water. Drive, a-c, 1200-hp, 2300-v, constant-speed motor.

Stack

Rust Engineering. Inner stack red brick 14 ft x 250 ft and outer stack of radial brick, same height. Air admitted at ground level to space between stacks. Double cap with air sweeping over cap of outer stack. Stack serves two boilers. Ash removed by Hydrovactor.

Soot Blowers

Diamond Power Specialty Corp. Automatic, sequential, air puff, 14 A2E units, four continuous blow retractable units, 300 psig.

Dust Collector—*Aerotec Corp.*

TURBINE-GENERATOR EQUIPMENT

General Electric Co. Tandem compound, 21-stage, 60,000-kw, 1250-psig, 950-F, 1.5-in. Hg abs. turbine, 5 points of extraction, 3600-rpm, 70,588-kva, 12,500-v, 60-cycle, 3-phase, hydrogen-cooled (0.5 lb. hydrogen press.) generator.

Exciter

General Electric Co., 1200 rpm, 200 kw. 250 v, shunt wound. Drive, G. E. 300-hp, 2300-v motor.

Condenser

Allis-Chalmers, 45,000 sq ft, two-pass, horizontal, surface condenser. Water inlet at top, outlet at bottom; common water box; admiralty tubes.

Air Ejector

Allis-Chalmers, steam jet, two-stage, twin element, surface intercooler and aftercooler; 350 psig steam press. A-C hogging jet.

CONDENSATE AND FEEDWATER SYSTEM

Condensate Pumps

Allis-Chalmers, two vertical, 14 in. x 8 in. two-stage, single suction, 875 gpm, 250 ft total head, 1170 rpm. Drive: a-c, 100-hp, 440-v motor.

Circulating Pumps

Allis-Chalmers, two vertical, 42 in. x 30 in, 21,600 gpm.

Boiler Feed Pumps

Allis-Chalmers, one (with one spare for two units) 6 in. x 5 in., 7-stage, doubleton, centrifugal pump, 1190 gpm, 4250 ft tdh, 3580 rpm, automatic bypass controlled by Bailey Flow Meter. Drive, a-c, 2000-hp, 2300-v, constant speed motor.

Closed Feedwater Heaters

Griscom Russell Co. U-tube, horizontal: one 3rd stage, 2807 sq ft, #15 gage, 70–30 cupro-nickel; one 7th stage, 1470 sq ft, #15 gage, 70–30 cupro-nickel; one 10th stage, 1470 sq ft #15 gage, 70-30 cupro-nickel; one 15th stage, 1647 sq ft, #18 gage, arsenical copper; one 18th stage, 2130 sq ft #18 gage, arsenical copper.

Drain Controls—*Fisher Governor Co.*

Heater Drain Pumps

Worthington Pump and Machinery Corp. Low pressure heaters: one 2-stage 1800 rpm, 200-gpm, 259 ft tdh. Drive, a-c, 25-hp, 440-v motor. High pressure heaters: one 3550 rpm, 100 gpm, 88 ft. tdh. Drive a-c, 5-hp, 440-v. motor.

Deaerator

Worthington Pump and Machinery Corp., 640,000-lb. per hr double shell, steam jet type; max. oper. press. 52 psig, storage tank 2850 cu ft.

Evaporator

Griscom-Russell Co., one horizontal Bentube, 18,000 lb. per hr.

Water Softener

Worthington Pump and Machinery Corp. Hot process lime and soda.

MISCELLANEOUS PUMPS AND COMPRESSORS

Ash Sluice System

Allen-Sherman-Hoff, two A-S-H ash transfer pumps, 1100 gpm; one A-S-H bilge pump, 1100 gpm; one A-S-H Hydrovactor, 4 in. x 6 in., 150 psig supply. Two *Allis-Chalmers*, ash sluice pumps, 150 psig, 1500 gpm. All pumps are motor driven.

Screen Wash

Allis-Chalmers, two 8 in. x 6 in., 1500 gpm, 250 ft tdh, 1760 rpm. Drive 150-hp, 2300-v motor.

Service Water and Fire Pump

Allis-Chalmers, one 1000 gpm, 246 ft tdh, 1750 rpm., motor-driven.

Evaporator Feed

Ingersoll-Rand, two 3450 rpm, 150 ft tdh. Drive, a-c, 5-hp, 440-v motor.

Chemical Feed—*Milton Roy Co.*

Station Air Compressor

Worthington Pump and Machinery Corp., Type YC-2, vertical angle, double acting, two stage, water cooled, with intercooler, aftercooler and 3-step variable capacity control. 100 psig, 541 cfm free air.

Soot Blowing Air Compressors

Worthington Pump and Machinery Corp., two Type DC-2 Horizontal, duplex, two stage, water cooled, with dual control, 500 psig, 552 cfm free air. Drive, 200-hp, 2300-v motor.

Control Air Compressors

Ingersoll-Rand, two Class ER-1, Horizontal, straight line, single stage.

Sump Pumps—*Yeomans Brothers Co.*

PIPING AND VALVES

Piping all electrically welded and furnished by *Pittsburgh Piping and Equipment Co.* Chrome-molybdenum piping for high-pressure lines and normal carbon steel for low-pressure lines.

Valves of cast steel furnished by *Wm. Powell Co.* Over one-third of major valves are motor operated and served by remote control from central operating room.

INSTRUMENTS AND CONTROLS

Combustion and Superheat Control—*Leeds & Northrup Co.*
Feedwater Control—*Bailey Meter Co.*, 3 element.
Level Controls—*Fisher Governor Co.*
Flowmeters—*Bailey Meter Co.*
Pressure Recorders—*Bailey Meter Co.*
Temperature Recorders—*Leeds & Northrup Co.*
Conductivity Recorders—*Leeds & Northrup Co.*

Liquid Levels

(Recording) *Bailey Meter Company.* (Indicating) *Yarnall-Waring Co.*

ELECTRICAL EQUIPMENT

Transformers

MAIN POWER TRANSFORMERS—three *Westinghouse Electric Corp.* 21,667 kva, 69,000/12,000 v. Oil-filled self-cooled, single-phase transformers per unit.

STATION AUXILIARY TRANSFORMER—One *Westinghouse Electric Corp.* 7500 kva, 69,000/2400 v. Oil-filled, self-cooled, three-phase transformer for present station.

UNIT AUXILIARY TRANSFORMER—One *Westinghouse Electric Corp* 6000 kva, 12,000/2400 v. Oil-filled, self-cooled, three-phase transformer per unit.

AUXILIARY POWER 440 VOLTS—Two *Wagner Electric Corp.* 750 kva, 2400/440 v. Dry type, three-phase transformers per unit.

Switchgear

69,000-v SWITCHGEAR—*Westinghouse Electric Corp.* "De-ion Grid" oil circuit breakers, outdoor type 69,000 v. 1200-amp. rating, pneumatic operated.

2400-v SWITCHGEAR—*Westinghouse Electric Corp.* Metal Clad Switchgear with "De-ion" air circuit breakers.

440-v SWITCHGEAR—Two I-T-E *Circuit Breaker Co.* Multumite substations per unit.

Main Electrical Switchboard—*Westinghouse Electric Corp.*

Batteries

Two 60-cell, 660-A.H. Exide control batteries for general station control.

Control Transformers

TRANSFORMERS FOR A.-C. CONTROL—Three *Wagner Electric Corp.*, 3 kva, 440/110-v. single-phase transformers connected as a three-phase bank for boiler and turbine a-c control.

Motors

Generally speaking all motors were furnished by *Allis-Chalmers Manufacturing Co.* Motors of over 125 hp are wound for 2400 v. and those of that rating and below for 440 v. All motors are line start.

MISCELLANEOUS

Car Dumper

Link-Belt—100 ton capacity, 20 cars per hr.

Crusher

American Pulverizer Co.—350 tons per hr, 12 in. max. coal.

Traveling Screens

Chain Belt Co.—two Rex Screens in series; first $^{1}/_{2}$-in. mesh; second $^{1}/_{4}$-in. mesh.

Chlorination

Wallace and Tiernan Co.

Survey Shows Present Power Situation

A digest of the report lately released by the National Security Resources Board showing scheduled deliveries of power generating equipment over the period 1948 through 1951, manufacturing capacity over those years, and the margin of utility reserve capability. This reserve, while at present critical in some areas because of unprecedented peak demands, should become satisfactory with equipment deliveries as scheduled.

A COMPREHENSIVE, authentic and up-to-date survey of the power situation, including full information on reserve capability, current equipment orders and scheduled deliveries, as well as manufacturing facilities to cope with estimated peak load growth, is contained in a report of the National Security Resources Board, dated December 6, 1948. Sources of data were major power pools, representing the private electric utilities; the TVA and other government power bodies; and the Federal Power Commission; together with an advisory group of some forty to fifty utility executives, officials of federal power agencies, and representatives of leading boiler and turbine manufacturers.

Survey Assumptions

The survey was predicated on the assumption that present trends of business activity will continue; that adequate materials will be available; that there will be no prolonged work stoppages; and that there will be no increase in defense production over that at present planned. The term "capability" as employed throughout the report, signifies dependable capacity without deduction for operating reserve to cover equipment outage.

Equipment receiving special consideration included large turbine-generators of over 10,000-kw rating, smaller turbine-generators of 4000 to 10,000 kw, hydroelectric generating units of more than 4000 kw, steam generating units operating at 450 psi and above, and power transformers of 500 kva and larger.

Despite the fact that electric utilities are exerting every effort to meet unprecedented demands, as are also the equipment manufacturers in speeding deliveries, it is quite apparent that the situation will be rather critical during the present winter. Throughout the country the margin of capabilities is inadequate for proper operating reserves, and in some areas it is likely that consumers will be called upon for voluntary conservation and load shifting during hours of peak demand. If water shortages should prevail in certain sections largely dependent on hydro power, the situation would become still more acute.

The estimated average margin between capabilities and loads for the end of 1948 (based on adverse hydro conditions) was 1.6 per cent. This would increase to 4.6 per cent by the end of 1949, 6.8 per cent in 1950 and 10.3 per cent in 1951, at which time the total electric utility capabilities will be about 72 million kilowatts. This is in contrast to approximately 50 million in 1947, or an increase of more than 40 per cent in a period of four years.

While these margins apply to the country as a whole, the 1951 figure for the Pacific Northwest is 5.2 per cent under average hydro conditions, and a shortage of 12.9 per cent would occur should adverse hydro conditions prevail. Next to the Pacific Northwest the area showing the smallest margin of reserve capacity is the Southeast where under normal conditions it is estimated to be 5.8 per cent, but only 2.9 per cent with adverse hydro conditions.

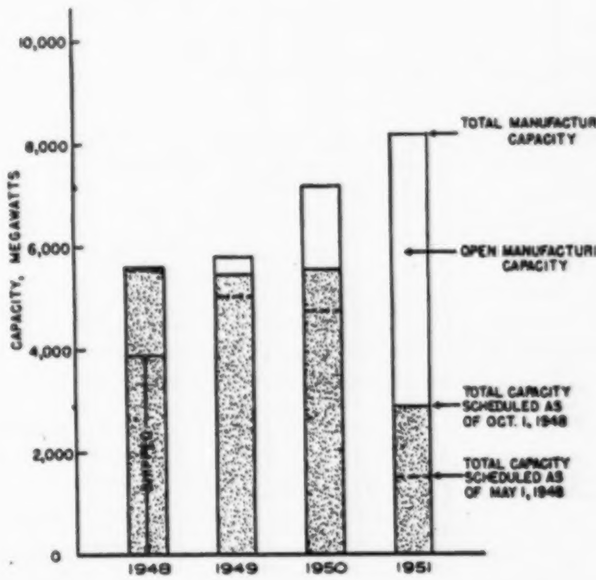


Fig. 1—Capacity for production of large and small turbine-generators

The report shows, for the four-year period 1948 through 1951, that nearly 24 million kilowatts of electric generating equipment is scheduled for shipment. Of this, approximately 75 per cent is in large steam turbine units, about 20 per cent hydro and the remaining 5 per cent small turbine-generators of from 4000 to 10,000 kw. These figures include capacity both for continental United States and for export. The division is 87 per cent for our electric utilities, 5 per cent for industrial plants and 8 per cent for export. Total shipments dur-

ing 1948 amounted to about 7 million kilowatts, leaving around 17 million kilowatts on order and scheduled for delivery during the next three years. Of this nearly 17

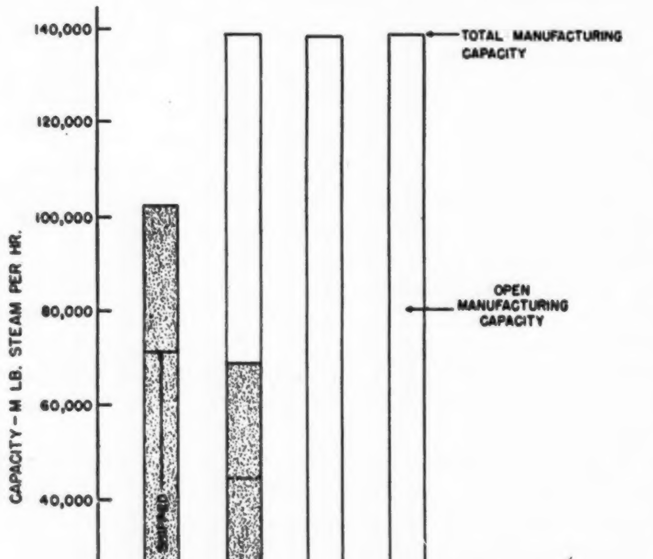


Fig. 2—Capacity for production of steam generating units on order and scheduled for delivery as of October 1, 1948; also open capacity

million kilowatts, 13,784,000 kw will be in steam turbines to supply which boiler capacity of 92,813,000 lb of steam per hour is on order or under construction at present. Table 1 shows schedules for 1948 through 1951.

Table 1

	1948	1949	1950	1951
Large turbine-generators, kw	4,631,240	4,915,000	5,515,500	2,817,500
Small turbine-generators, kw	986,600	535,000	...	...
Water-wheel generators, kw	1,620,200	1,341,860	1,055,300	430,850
Steam generating units, M lb per hr	102,203	68,857	23,056	900
Power transformers, kva	21,200,000	24,300,000	18,500,000	3,900,000

The foregoing totals include exports over the four-year period of 443,000 kw in large turbine-generators, 373,000 kw in small turbine-generators, 993,000 kw in hydro units of more than 4000 kw, and steam generating capacity of 14,827,000 lb of steam per hour.

Table 2 shows a breakdown of the total electric generating capacity (steam and hydro over 4000 kw) on order over the various regions of continental United States and abroad.

Table 2

Region	1948	1949	1950	1951
Northeast	1,307,250	577,400	1,241,300	745,000
East Central	957,500	1,517,500	900,000	680,000
Southeast	612,800	891,500	1,077,500	360,000
North Central	629,000	934,400	791,000	342,500
South Central	581,500	672,300	710,000	390,000
West Central	268,400	258,600	195,000	130,000
Northwest	474,500	469,600	501,200	299,100
Southwest	825,500	657,700	706,500	160,000
Utilities	5,656,450	5,979,000	6,122,500	3,106,600
Industrials	622,000	433,800	40,000	80,000
Outside Continental U. S.	959,600	379,860	408,300	61,750

It will be noted that over half the total capacity listed as destined for outside continental United States represents hydro power.

Manufacturing Facilities

From the information furnished by manufacturers' representatives it would appear that shop facilities for large turbine-generators were fully taken up during 1948 and will be in 1949; that there is still some open capacity for 1950 and considerable for 1951, beyond which no shipments are scheduled. The turbine builders still have some open capacities for 1949 and a large amount for 1950 and 1951. Builders of water wheels have no open capacity till late in 1950. Boiler manufacturers report that practically all steam generating equipment on order as of October 1, 1948, is scheduled for shipment before 1951. From this it is apparent that orders for such equipment are lagging behind those for turbine-generators. Attention is called to the fact that manufacturing capacity for steam generators is very large, providing the necessary materials for fabrication can be obtained.

Fig. 1 shows graphically scheduled deliveries and open manufacturing capacity for large and small turbine-generators over the four-year period; whereas Fig. 2 gives similar information for steam generating units. In Fig. 3 is shown the cumulative capacities of steam turbine-generators and steam generating units for electric utilities only, for continental United States, on order and scheduled for shipment.

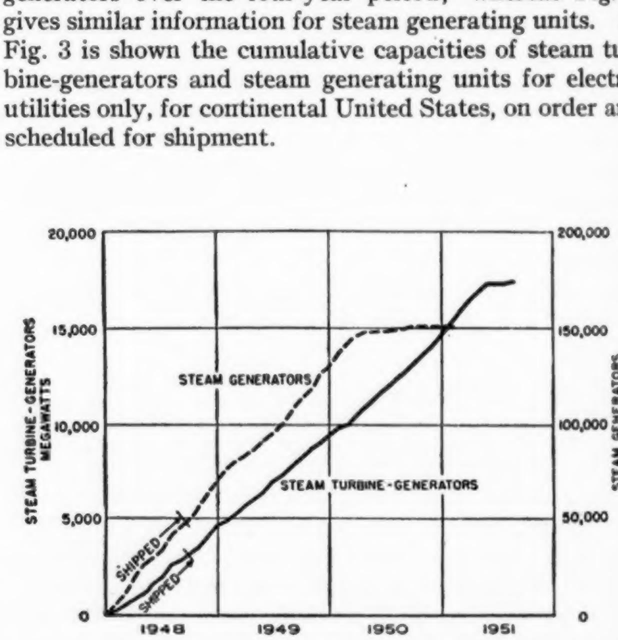


Fig. 3—Cumulative capacity of steam turbine-generators and steam generating units scheduled for shipment, 1948 through 1951, for continental United States only

Recalling that it has long served political strategy to accuse the electric utilities of lack of foresight in preparing adequately to meet growing load demands, it is significant to quote the following conclusions of the report:

"There are few industries in the United States that can equal this striking record of post-war expansion. The utility managements and the regulatory commissions have been cognizant of the tremendous importance of assuring an adequate national power supply and the results of their efforts toward this objective are shown in the magnitude of the construction program now in progress."

Control and Starting of Reheat Turbines

The following excerpts are taken from a paper delivered at the 1948 A.S.M.E. Annual Meeting and briefly abstracted in the December 1948 issue of COMBUSTION. Methods for controlling reheat turbines, including design of protective equipment, are indicated, and procedures for starting and shutting down large steam turbine units are discussed.

BY C. A. ROBERTSON

Steam Turbine Dept.,

Allis-Chalmers Mfg. Co.

FOR ordinary condensing turbines, speed governor control of main inlet valves and an overspeed governor operating close to the throttle valve, together with check valves on extraction lines to feedwater heaters, are sufficient to prevent excessive overspeeding of the turbine in case of sudden loss of load. With reheat units, however, the large volume of steam stored in the reheat piping and steam space of the reheater has an enormous potential energy which is not controlled by the main inlet valves. Therefore, it is necessary to provide some form of reheat protective equipment, such as intercepting valves and unloading valves in the reheat lines. For reheat turbines these valves are under control of the speed governor.

The intercepting valves are wide open at normal speed and begin to close at a predetermined overspeed. Unloading tests have shown that, in order to limit overspeed rise, the essential idea is to start these valves closing very soon after the tripping of the load and not to wait until the speed rises to actuate the overspeed governor or mechanism.

In addition to the intercepting valves, a steam unloading valve is also provided, which under normal operation is closed and steam-tight. This valve, however, following a load trip-out, opens by the action of the speed governor shortly after the intercepting valves begin to

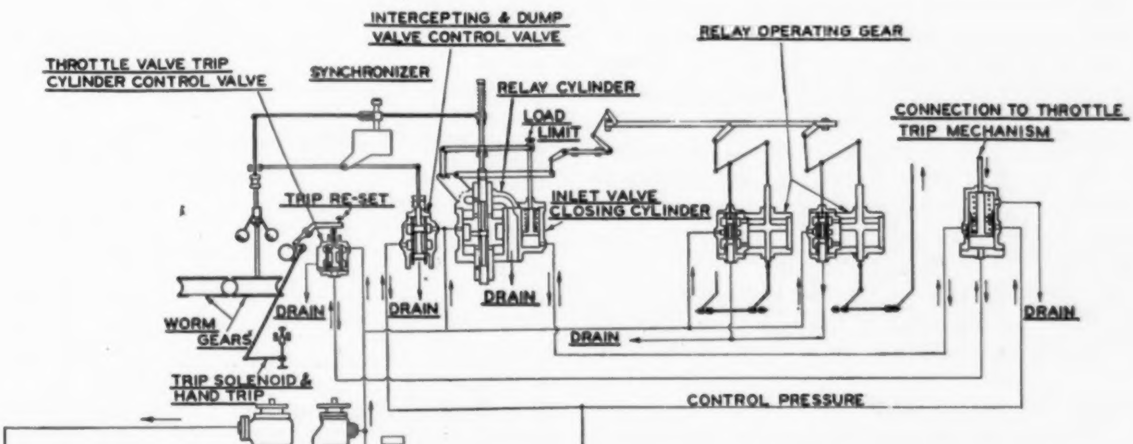


Fig. 1—Arrangement of turbine governing system including reheat control

close, and, in turn, relieves the steam in the reheat line at a point between the intercepting valve and the turbine, bypassing it to the condenser. The purpose of this valve is to reduce the stage pressure at the reheat inlet and also to keep this pressure near condenser value so

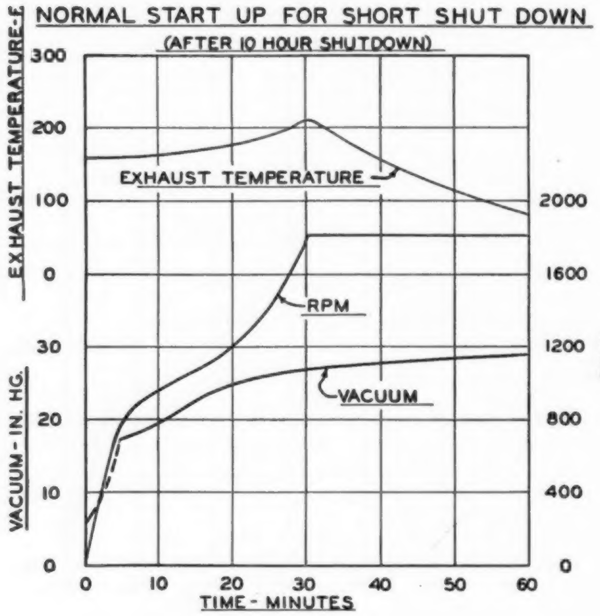


Fig. 2—Starting performance, 80,000-kw reheat unit, 1230 psig, 850 F reheat—29 in. vac.

that very little steam flows through the turbine blading between reheat and low-pressure exhaust, thereby reducing to an absolute minimum the possibility of turbine speed acceleration due to leakage steam or residual steam.

Fig. 1 illustrates the arrangement of the governing system, including reheat control, for an 80,000-kw turbine.

In the design of the protective equipment for a unit arrangement of one boiler per turbine, there are a few general ideas that are worth remembering.

1. Fundamentally, the protective equipment in a plant with a unit arrangement of one boiler per turbine should be interrelated with respect to both boiler and turbine.
2. Turbine overspeed, which may be almost as destructive as a boiler explosion, seems properly the principal concern when designing and preparing operating instructions for a reheat unit.
3. Protecting the turbine transcends the need for protecting the reheater and superheater upon loss of load.
4. Following the trip-out, the fuel feed to the boiler must be stopped very promptly.
5. Leakage of steam into the turbine during overspeeding following load trip-out is undesirable from the standpoint of holding the maximum overspeed to safe limits.
6. Modern large steam turbine units equipped with hydrogen generator cooling have a no-load resistance that is extremely low; therefore, relatively small quantities of steam in the neighborhood of one or two per cent of full load flow can cause undesirable overspeeding.

It is important that manufacturers and users both insure that high-pressure lines are not connected so that their discharge steam can pass through any turbine blading during emergency conditions. The turbine throttle and inlet valves upon closing must not be bypassed in any conceivable manner.

Starting and Shutting Down Procedures

Certain procedures in starting and shutting down large steam turbine units, both reheat and non-reheat, have been investigated and developed over a period of years. These methods cover the starting of steam turbine units for two extremes of conditions; namely, starting from cold or starting following a short shutdown.

As more and more large units are installed, frequent starting and shutting down of these units will be necessary. This will also apply to reheat units; therefore the question as to the comparative flexibility of reheat to non-reheat units becomes an important factor. Existing data based on Allis-Chalmers tests indicate that the flexibility of the reheat units with reference to frequent starting and shutting down is fully suitable for modern central station service.

Fig. 2 shows the normal start after a short shutdown of an 80,000-kw reheat unit. Figs. 3 and 4 indicate the start of the same unit after a long shutdown, the former covering the time up to the point of applying load and the latter covering the time from the first admission of steam to the point of full unit loading.

Thermal stresses introduced because of the great temperature difference between steam and metal are highest when the unit is cold and hot steam is admitted to the turbine cylinder. To control these thermal stresses within desired limits, means can be provided for meas-

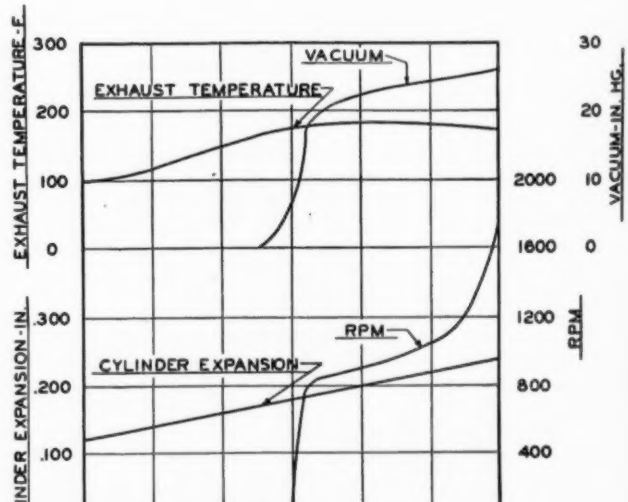


Fig. 3—Normal starting from cold procedure, up to point of applying load

uring the rate of expansion of the turbine cylinder of the high-pressure end. In this manner the rate of expansion may be held to a fixed value per hour, for instance 0.060 in. per hour normal or 0.120 in. in emergencies.

The time required for cold starts is not a critical factor as these occur probably only once in a year or once in a

longer period. Adherence to the idea of limiting thermal stress to a fixed value per hour, however, reduces maintenance of turbines.

TABLE 1—RECOMMENDED STARTING TIME RELATIVE TO INITIAL CYLINDER EXPANSION, 80,000-KW REHEAT UNIT, 1230 PSIG, 850 F, 850 F REHEAT, 29 IN VAC.

Initial Cylinder Expansion, In.	Time Bringing Up to Speed	Time Heating on Turning Gear	Total Starting Time
0.100	45 Min	2 Hr	2 Hr, 45 min
0.200	40 Min	1 Hr	1 Hr, 40 min
0.300	35 Min	1/2 Hr	65 Min
0.400	30 Min	1/4 Hr	45 Min
0.500	30 Min	0	30 Min

Table 1 gives the starting method depending upon the time the unit has been shutdown; it is based upon the initial expansion at the cylinder at the starting time relative to that of a cold unit.

Procedure for Normal Start-up

The following outline is indicative of the procedure to be followed in the normal start-up of a unit boiler reheat plant.

1. Drain superheaters, reheaters, and piping adequately without unnecessary loss of steam.
2. Start fire in boiler.
3. If lines are cold, heat up high pressure lines and also warm up reheat lines by closing intercepting valves and bypassing high pressure steam into one of the two

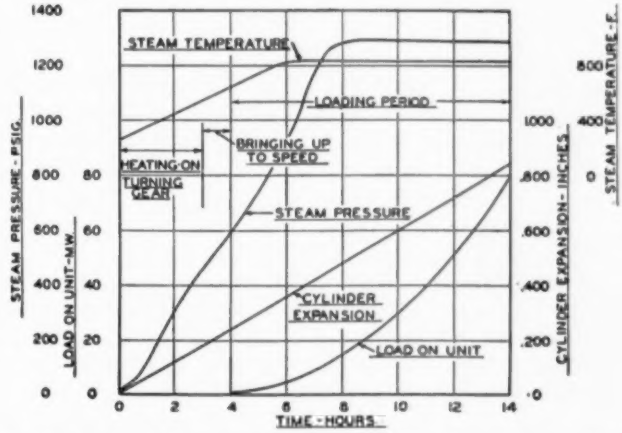


Fig. 4—Normal starting from cold procedure, from first admission of steam to full load

reheat lines to allow this steam to circulate through reheat lines, the drains being connected to the condenser and the excess steam valved to a low pressure heater. Heating may be performed with only a low pressure in the boiler.

4. If turbine is cold, the warming up can be started as soon as the boiler pressure reaches a few pounds, and by means of this early start, time can be saved accordingly. The initial heating normally for a cold turbine is about 3 hr; however, the time is somewhat governed by the expansion of the turbine cylinder to a value of approximately 0.150 in.
5. Following this initial heating period, in case of a cold start, the turbine is started rolling and the speed is gradually increased.
6. After the turbine has been brought up to speed, synchronize on the line and apply load on the unit, as shown in Fig. 4, if the start-up is from cold. In case of a short shutdown, the rate of loading can be applied much faster, as the metal temperatures of the turbine casings and rotor are relatively high, and the change in the thermal expansion is of smaller magnitude.
7. For normal overnight or week-end shutdown the procedure is the same as for a non-reheat unit, the load being gradually reduced to zero, the unit tripped out and put on the turning gear after coming to rest. The steam pressure in the boiler is not deliberately reduced in any case, because resumption of service on start-up promptly encourages retention of boiler pressure, instead of its useless dissipation. Steam lines are adequately above any saturation temperatures to require draining. Economy is improved by making all possible attempts to preserve or hold boiler steam pressure.

FACTS AND FIGURES

Combustion rates as high as 65 lb per sq ft per hr may be obtained when burning lignite on a forced-draft traveling grate stoker with a rear-arch furnace.

•

The annual dollar value of coal exceeded the aggregate of iron ore, gold, silver, zinc, lead and other metals produced in the United States in 1946, according to Bituminous Coal Institute.

•

It is common to specify 20 per cent excess capacity when selecting an induced-draft fan to take care of higher excess air than anticipated, worn or dirty fan blades, and excess output above rating.

•

According to recent estimates the world's proved reserves of crude oil in the ground amount to about 70,000 million barrels, of which approximately half is in the Middle East.

•

Heat transfer rates, in Btu per sq ft per hr in a modern high-capacity steam-generating unit, will range from 50,000 to 80,000 for the furnace walls; 8000 to 12,000 for the superheater and 2000 to 5000 for the boiler convection surface.

•

During the past year the first experimental field-welded aluminum pipe lines for carrying crude oil were laid in Arkansas and Louisiana.

•

The first large turbine to operate at 1050 F is a 100,000-kw, 3600-rpm, tandem-compound, triple-flow unit which went into service on November 30, 1948, at the Sewaren Station of the Public Service Electric and Gas Company of New Jersey.

•

The labor cost per ton of bituminous coal in Great Britain in 1946 was $4.60, compared with $2.06 in the U. S. In the same year the British coal miner averaged $23.91 in his weekly earnings, while the U. S. miner was getting paid $58.03 per week, on the average.

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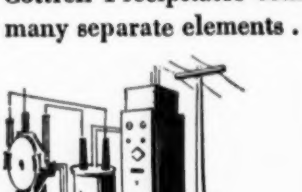
▶ *Western Precipitation Corporation is the organization that installed the first successful* COTTRELL *Precipitator over 39 years ago, still operating efficiently . . . and has consistently developed new refinements, new techniques, new applications that today have made it world famous in the science of recovering dusts, fly ash, mists, fogs and other suspensions from gases.*

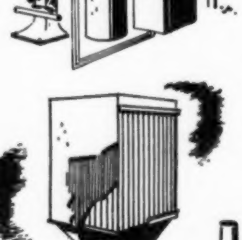
This is the first of a series of advertisements briefly outlining the important elements that go to make up a COTTRELL installation. Only long experience coupled with highest engineering ability, can assure the proper combination of these elements into a COTTRELL installation best suited to *your particular requirements*!

Basically, a Cottrell Precipitator consists of three major divisions each in turn consisting of many separate elements . . .

1. THE ENERGIZING SYSTEM, as its name implies, is the portion of the unit wherein the power is brought in, the voltage stepped up, then rectified to provide the unidirectional high voltage current supply for the Electrode System.



2. THE ELECTRODE SYSTEM consists of the high-tension ionizing electrodes and collecting electrodes through which the suspension-laden gas is passed to be cleaned. These electrodes can be of various designs, shapes and patterns and are equipped with various "rapper" arrangements which assist in keeping the electrodes clean of recovered materials.



3. THE HOUSING OR SHELL includes the structure containing the Electrode and Energizing Systems as well as the gas ducts and distributing system, the hoppers for receiving the collected material and other miscellaneous equipment.

Each of these three major divisions, together with their many individual parts, must be carefully engineered into ONE integrated and precisely-balanced unit to provide the successful and continuously-operating COTTRELL Precipitator. This series will take these major units apart to show in greater detail how the individual parts function and the varying types of design and construction. Watch for them.

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Deposit Formations on Boiler Tubes

By R. S. YOUNG and A. J. HALL
Central Laboratory, Nkana, Northern Rhodesia

Barnacles appeared when conditioned water was allowed to cool and stand some time in a boiler after taking the latter off the line. They were accompanied by pitting beneath the deposits. Investigation showed that phosphate and sulfate together are necessary for the formation of such barnacles and that copper salts appear to be accelerators for the growth of these deposits. Therefore, owing to the widespread occurrence of phosphates and sulfates in conditioned boiler feedwaters the importance of draining a boiler as soon as practicable after cooling down is emphasized.

AT THE power plant of Nchanga Consolidated Copper Mines Limited, Chingola, Northern Rhodesia, the formation of peculiar deposits, resembling barnacles, in boiler tubes and drums was finally traced to the practice of allowing a boiler full of conditioned water to cool slowly and stand for some time after coming off the range. Beneath these brown, yellow or green hemispherical deposits the steel was pitted. Chemical analysis of the barnacles indicated that they were largely composed of hydrated iron oxide, together with small quantities of phosphate, sulfate and copper. The composition of such deposits was naturally variable, but a typical analysis would be, in percentages, Cu 1.1, PO_4 1.0, SO_4 0.07, faint traces of sodium, alumina, silica, lime, magnesia and the balance hydrated iron oxide.

The Nchanga boiler feed is entirely return condensate plus evaporator makeup, and at this period the water was conditioned with sodium hydroxide, sodium phosphate and sodium sulfate.

The invariable presence of phosphate, copper and sulfate in these barnacles led to the belief that, as the water cooled, the sparingly soluble cupric orthophosphate was deposited at points in the boiler drums and tubes in the form of small, round nodules or barnacles. Attack of the steel proceeded beneath these deposits either through a local concentration of alkaline salts or by a galvanic action from the copper compound (4).[1]

The view that deposition of salts from the conditioned water, on cooling and standing in the boiler system, was responsible for these nodules, was proved by several tests at the power plant. Boilers operating under the same conditions were taken off the range in pairs; one was allowed to cool naturally, and the other was drained as soon as practicable. In every case the latter was free of barnacle formation whereas the former had a large number of nodules in the tubes and drums.

A further confirmation was forthcoming during the same period, since tests were underway at Nchanga to compare boiler operation on untreated feedwater with that on conditioned water. It was found that barnacle formation was practically absent when the boilers were operated on unconditioned water, even when allowing the boilers to cool slowly and stand for some time before draining. The fact that barnacle formation was not entirely absent under these conditions can be attributed to the well-known difficulty of removing all conditioning salts from a boiler system in a short period. Traces of salts remain in the boiler water for many months after their addition has ceased and the boiler has been refilled.

The formation of these deposits in the boiler system at Nchanga could thus be competely controlled by operating on unconditioned water, or, if a conditioned water were employed, by draining the boiler as soon as practicable after it was taken off the range. Since this practice was instituted, no further trouble with barnacle formation has been experienced.

At that time we believed that the primary cause of the deposits was the sparingly soluble cupric orthophosphate derived from the phosphate of the conditioning agent and the copper within the boiler system. Copper was considerably higher at Nchanga than in the usual boiler feedwater, due to the fact that for several years after the station was put in service, certain makeup, as well as cooling water, was obtained from mine supply which contained a small but constant quantity of copper in the form of copper bicarbonate. Power plant water supplies were later changed to a copper-free source, but a considerable quantity of copper had by this time found its way into the boiler system.

It was later noted, however, that other power plants in Northern Rhodesia operating on water conditioned with sodium phosphate, hydroxide and sulfate experienced the same formation of barnacles with pitting of the steel beneath the deposit. In view of the widespread use of these conditioning agents it was deemed desirable to investigate more closely the mechanism of the formation of such deposits. The laboratory experiments and results described below are the outcome of this decision.

Experimental Work

Sections of a boiler tube were cut approximately 4 in. long by 1 in. wide and were carefully machined and cleaned, then placed in glass bottles containing 400 ml of distilled water. Boiler feedwater reagents and copper compounds were added to the solutions in the quantities given in the accompanying table. The bottles were

[1] Figures in parentheses refer to literature cited at end of article.

covered with bakelite screw caps, but these were not screwed down tightly. In this way air could enter and the test vessels were therefore comparable to a boiler off the range.

In Nchanga conditioned boiler water containing small amounts of copper, the following quantities of salts were normally present, in grams per liter: Cu, 0.003; $Na_3PO_4 \cdot 12H_2O$, 0.2807; NaOH, 0.10; and Na_2SO_4, 0.40. The solutions used in the laboratory experiments were made up to contain ten times the above quantities. This was done because it was felt that, although boiler water solutions are more dilute, any deposits forming in boilers have a much larger reservoir to draw from than deposits under laboratory conditions where the volume of solutions used must necessarily be very much smaller. Furthermore, it was necessary in the laboratory tests that barnacles be formed in a reasonable period of time, and that the weight of the deposits be sufficient for a chemical analysis.

within the pH range of 8.3 to 12, wherein steel is only slightly susceptible to dissolution by boiler water (3).

The experiment was discontinued after 69 days, the test pieces were photographed and the deposits removed for analysis. The appearance of the tubes is illlustrated in the photographs here reproduced as Figs. 1 to 6. The tubes 1, 4, 6 and 9 (see table) on which loose furry deposits of ferric hydroxide were found, did not show any pitting after removal of the deposits. The deposit was so loosely adherent that the tube could not be removed from the test solution for a photographic record without dislodging the deposit. The oxidation removed a very thin layer of iron from the entire surface of the tube, so thin in fact that the machine marks on the tube were still visible. Under the adherent barnacles on tubes 5, 7 and 10, however, were deep corrosion areas and pits, many being 0.5 mm in depth. This pitting was similar in every respect to that previously found beneath nodules in boilers.

COMPOSITION AND pH OF SOLUTIONS, AND APPEARANCE OF BOILER TUBES

Sample No.	Salts Present in 400 Ml Distilled Water	Initial pH	Final pH	Appearance of Tubes: After 3 Hr	After 9 Days	After 69 Days
1	....	6.4	7.8	Oxidation (rusting) commenced	....	Considerable oxidation. Thick fur of ferric hydroxide
2	1.123 g $Na_3PO_4 \cdot 12H_2O$	11.1	9.1	No oxidation	....	No oxidation
3	0.4 g NaOH	11.0	9.6	No oxidation	....	No oxidation
4	1.6 g Na_2SO_4	7.5	7.9	Tarnishing	Oxidation	Strong oxidation. Thick fur of ferric hydroxide
5	1.123 g $Na_3PO_4 \cdot 12H_2O$ + 0.4 g NaOH + 1.6 g Na_2SO_4	11.1	9.8	No oxidation	Barnacles commencing	Greenish-brown adherent deposit over $^1/_3$ area, starting at the top and working down
6	0.047 g $CuSO_4 \cdot 5H_2O$	6.5	7.6	Stronger oxidation than 1	....	Considerable oxidation. Ferric hydroxide formed all over tube and suspended in water
7	0.047 g $CuSO_4 \cdot 5H_2O$ + 1.123 g $Na_3PO_4 \cdot 12H_2O$	10.9	9.1	No oxidation	Barnacles	Small spots of yellowish deposit all over tube with larger ones at bottom
8	0.047 g $CuSO_4 \cdot 5H_2O$ + 0.4 g NaOH	11.3	9.6	No oxidation	....	No oxidation
9	0.047 g $CuSO_4 \cdot 5H_2O$ + 1.6 g Na_2SO_4	7.5	5.9	Oxidation	....	Thick fur of ferric hydroxide on tube, and water also thick with ferric hydroxide
10	0.047 g $CuSO_4 \cdot 5H_2O$ + 1.123 g $Na_3PO_4 \cdot 12H_2O$ + 0.4 g NaOH + 1.6 g Na_2SO_4	11.3	9.6	No oxidation but small deposit forming at upper edge	Deposits forming faster than No. 5	Large greenish-brown deposits starting from edges of tube and spreading over the surface
11	1.123 g $Na_3PO_4 \cdot 12H_2O$ + 0.1 g $Cu_3(PO_4)_2 \cdot 3H_2O$	..	...	No oxidation	....	No oxidation

The pH rose during the course of the test with samples 1, 4 and 6 where considerable quantities of ferric hydroxide were formed. It is not clear why sample 9, where ferric hydroxide was also produced, should have decreased in pH. Samples 5, 7 and 10 decreased in pH since some of the reagents were withdrawn from solution to form deposits. Samples 2, 3 and 8 also dropped in pH due to the absorption of carbon dioxide from the air by dilute alkalies (5).

The course of the formation of deposits is also shown in the table. The rapid oxidation or rusting of samples 1, 4, 6 and 9 is noteworthy. With samples 5, 7 and 10 the formation of barnacles occurred in a few days, No. 7 leading and followed by 10 and 5, respectively. The appearance of these barnacles in samples 5, 7, and 10 was identical with that of deposits formed in boilers where conditioned water was allowed to cool slowly. Samples 2, 3, 8 and 11 remained entirely free of oxidation or deposits. It is generally assumed that salts such as sodium phosphate yield a soluble cathodic product and an insoluble anodic product which forms a closely adherent protective skin, usually invisible, over the metal (5). In distilled water about 0.1 g NaOH per liter is sufficient to keep corrosion at a minimum. More NaOH is required if other dissolved salts are present, probably owing to the destruction of protection offered by the surface film of ferrous hydroxide. Samples 2, 3 and 8 remained well

It appears that those portions of a metal least accessible to oxygen are most prone to undergo corrosion, whereas those portions most accessible to oxygen are least likely to corrode (2). If oxygen is present in sufficient quantities that the ferrous ions, as they escape through the film, are precipitated *in situ*, the attack is decreased; but if the formation of a solid product takes place at a distance from the surface, the opposite effect is observed. The corrosion product provides an oxygen shield and corrosion is accelerated in those areas already under attack. As the products of corrosion form over a pit, the metal at the bottom of the pit will become more anodic (5).

The analysis of the barnacle deposits is given below:

	No. 5	No. 7	No. 10
Weight of deposit in grams	0.4461	0.0482	0.9326
% Fe	46.9	64.4	47.7
% PO_4	7.3	5.7	7.2
% SO_4	3.0	0.9	4.2
% Cu	.....	Trace	0.029

Owing to the small size of the sample it was not possible with our facilities to do a complete analysis, but it appears that the deposits were largely hydrated iron oxide with some ferric phosphate and a little ferric sulfate. Unfortunately, we did not have available equipment for the X-ray examination of these deposits, which has frequently been of great service to other investigators (1). Copper was very low, and the discrepancy in copper

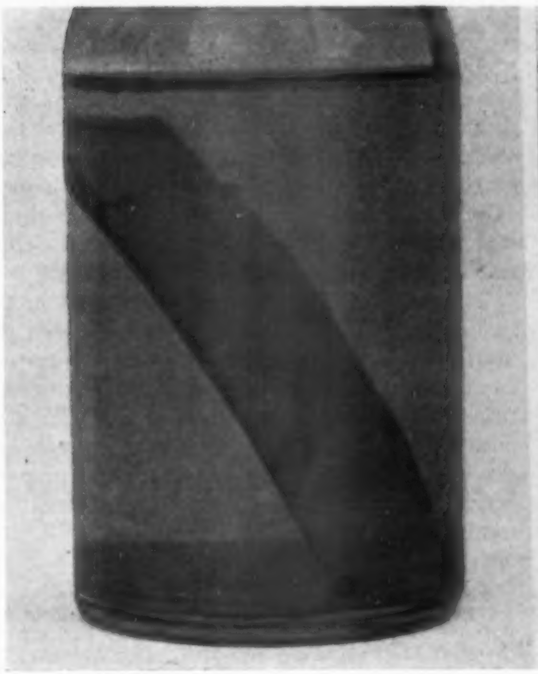

Fig. 1

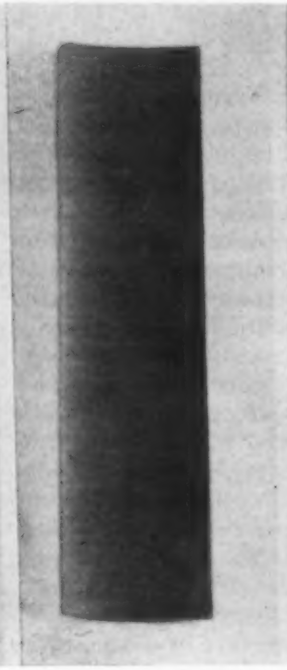

Fig. 2

Fig. 3

Fig. 1—Thick loose deposit of ferric hydroxide on boiler tube in the following solutions:

Sample 1. Distilled water only. Sample 4. Distilled water + sodium sulfate. Sample 6. Distilled water + copper sulfate. Sample 9. Distilled water + sodium sulfate + copper sulfate.

Fig. 2—Clean boiler tube, characteristic of samples standing in the following solutions:

Sample 2. Distilled water + sodium phosphate. Sample 3. Distilled water + sodium hydroxide. Sample 8. Distilled water + sodium hydroxide + copper sulfate. Sample 11. Distilled water + sodium phosphate + copper phosphate.

Figs. 3, 4, 5—Barnacle deposits formed on tubes standing in the following solutions:

Fig. 3, Sample 5. Distilled water + sodium hydroxide + sodium phosphate + sodium sulfate. Fig. 4, Sample 7. Distilled water + sodium phosphate + copper sulfate. Fig. 5, Sample 10. Distilled water + sodium hydroxide + sodium phosphate + sodium sulfate + copper sulfate.

Fig. 6—Pitted surface of sample 10 boiler tube beneath the deposit. Compare with Fig. 5. Light areas are pitted portions of steel underneath dark barnacle areas of Fig. 5

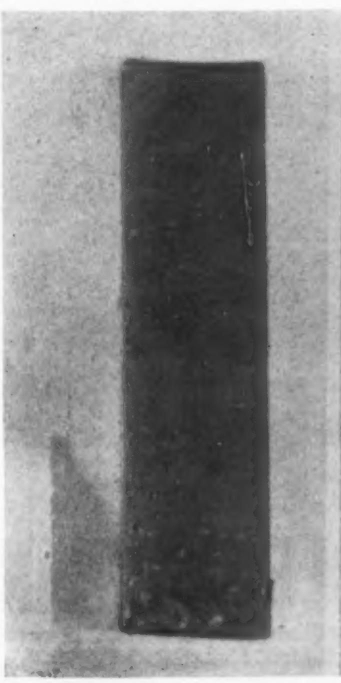

Fig. 4

Fig. 5

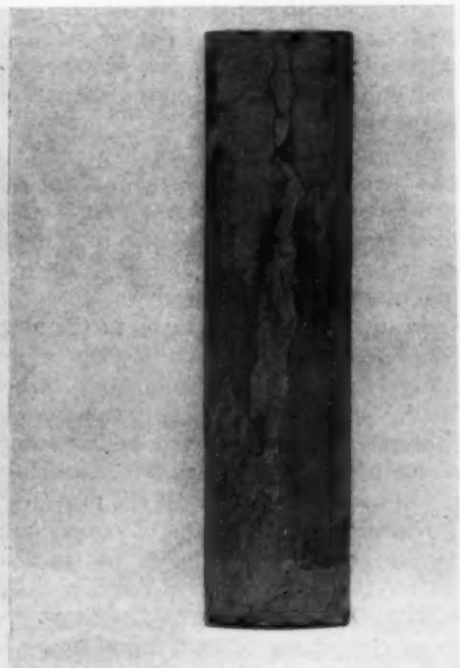

Fig. 6

figures between the results of laboratory deposits and actual boiler deposits can probably be explained by the assumption that an appreciable quantity of metallic copper was present on the boiler surface and was unavoidably collected with the sample of barnacle deposit.

As we could not find data on the solubility of copper phosphate in water and in solutions of conditioning agents we determined these solubilities at a temperature of 25 C. Copper phosphate is souble in distilled water to the extent of 0.1–0.2 mg per 100 ml, and in the various combinations of sodium phosphate, sodium hydroxide and sodium sulfate used in water conditioning to the extent of 0.02–0.04 mg per 100 ml at room temperatures.

In addition to the tests on boiler tubes described above, two sections of tube were later immersed in solutions containing 400 ml of distilled water plus 1.123 g $Na_3PO_4 \cdot 12H_2O$, plus 0.1 g $Cu_3(PO_4)_2 \cdot 3H_2O$. In one case the boiler tube was placed in the solution and allowed to remain at room temperature as in the other tests. This is listed as sample 11 in the table. The second tube was placed in the solution and the latter boiled for one hour before allowing to stand at room temperature. After four weeks there was no evidence of a deposit on either tube. It is apparent that copper phosphate in the presence of sodium phosphate alone does not lead to the formation of barnacles.

Discussion of Results

Trisodium phosphate, sodium hydroxide, sodium sulfate or copper sulfate, when added singly to distilled water did not cause the formation of typical adherent deposits or barnacles on surfaces of boiler tubes. In the presence of sodium hydroxide or sodium phosphate in solution the boiler tube remained completely unoxidized and free of nodules. With sodium sulfate or copper sulfate in solution oxidation occurred and a non-adherent coating of ferric hydroxide was formed over the boiler tube. The addition of copper sulfate to sodium hydroxide solution did not produce oxidation of the boiler tube.

The combination of sodium phosphate and sodium sulfate, or sodium phosphate and copper sulfate, leads to the production of barnacles. The presence of a phosphate and a sulfate is essential to the formation of these characteristic deposits.

Copper appears to act as an accelerator in the formation of barnacles, since those formed on tubes 7 and 10 appeared before those on tube 5 where copper was absent. The addition of copper to a solution of sodium phosphate, hydroxide and sulfate also resulted in a much larger deposit of nodules than when copper was absent.

Copper in the form of phosphate, in the absence of a sulfate, does not form barnacles. Copper in natural waters is largely present as the sulfate or bicarbonate and is presumably precipitated as copper phosphate by the sodium phosphate of conditioned boiler water. Small amounts of copper phosphate go into solution or remain in suspension in boiler water. In the presence of a sulfate and phosphate these traces of copper are able to accelerate the growth of barnacles and to a small extent enter into the composition of the deposits either by occlusion with the other salts or by direct deposition.

In view of the pitting of steel found under barnacles in both boiler practice and laboratory tests it is suggested by the authors that the introduction of sulfates in any form into the boiler system be avoided. If, for any reason, such as the use of sodium sulfate to give a sulfate : hydroxide ratio recommended in some quarters to prevent caustic embrittlement, or the employment of sodium sulfite as a scavenger for dissolved oxygen, making the presence of sodium sulfate or sodium phosphate unavoidable, the boilers should be emptied as soon as practicable after taking off range. Slow cooling and long standing will result in the formation of deposits underneath which attack of the steel proceeds.

The fact that this deposit formation has apparently not hitherto attracted much attention can probably be attributed to the operation of nearly all power plants at capacity during the past ten years. Under these conditions little time would be lost in draining a boiler after a steaming period prior to inspection and repairs, and even with the presence of sulfate and phosphate in the boiler water the tendency for nodule formation would be minimized.

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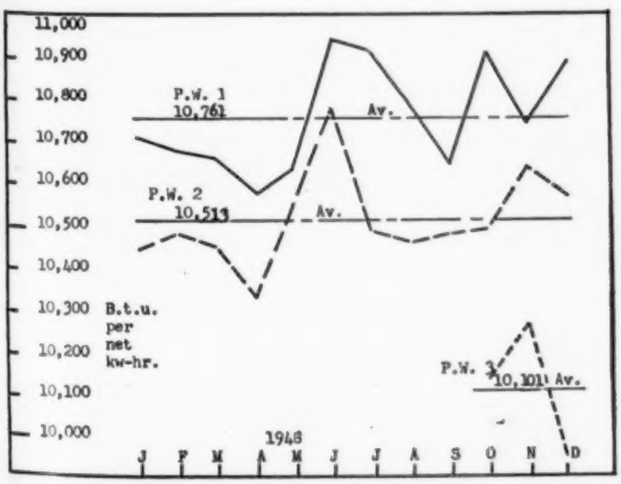
Port Washington 1948 Performance

For some years past it has been COMBUSTION's privilege to report, in its January issue, on the previous year's performance and experiences of Port Washington Station of the Wisconsin Electric Power Company. This plant, laid out on the unit system, now has in operation three units of 80,000 kw rating; a fourth and a fifth, of like capacity, are on order. The three months' net heat rate of the latest unit is 10,101 Btu per kwhr.

MINIMUM outage time, encouraged by inadequate system reserves, characterized 1948 operation. Units 1 and 2 operated 96 per cent of the year. For the last two years the availability of these single-boiler-per-turbine units has averaged 95.9 per cent.

Unit 1 had two forced outages due to recurring tube-joint leakage trouble. Tie-backs of a rear-wall furnace tube did not allow its downward travel in cooperation with $1^1/_2$ in. downward mud-drum travel, and its joint with the latter leaked on several occasions until the tie-back trouble was disclosed and corrected. However, boiler No. 1 availability for the year was 96.9 per cent. It is not positively free of the screen-tube corrosion trouble previously described in this publication. During the October outage, a minute leak in one screen tube was found and repaired by welding. The corrosion rate is low and is limited in total extent.

Unit 2 had two short outages due to erroneous operation of automatic equipment, no longer in use. Much trouble with steel-tube leakage in the high-pressure heaters has prompted plans to change to copper-nickel tubes in this unit.



Comparative heat rates of three units

Approximately 50,000 tons of western Kentucky coal of 2040 F ash-fusion (softening) temperature was burned in the three boilers recently, without increasing excesss air and without furnace dirtiness trouble. In fact, this mid-western coal was found superior to the much-deteriorated eastern coal in many respects. That the boiler plant utilizes it acceptably seems significant.

None of the Port Washington boilers has ever been turbined or acid cleaned.

A weighed-water test of the turbine No. 3 during normal operation in December proved it to be close to guarantees. The following list of starting experiences concerns only the turbine, for the boiler was ready several weeks earlier and was started without incident.

Table 1

OUTPUT AND ECONOMY DATA

Unit No.	Period (Incl.)	Net Output 10^6 Kw-hr.	Load Factor %	B.t.u./Kw-hr. Net
1	1948	559.97	84.3	10,761
	1935*-48	5,782.191	66.5	10,835
2	1948	574.122	86.2	10,513
	1943*-48	2,669.992	77.7	10,581
3	1948*	117.551	78.5	10,101

*Nov. 22, Oct. 27, and Oct. 5 startings, respectively

No. 3 Turbine Starting Experiences

September 26. Initial starting attempt was delayed because turbine oil drained to the emergency tank when the oil pump started. Suspected leakage of the emergency-drain valve caused delay until an oil cooler drain cock was found inadvertently opened.

September 27. Intercepting valves did not open and close properly, requiring inspection and minor changes.

September 29. Turning-gear reduction-gear bearing seized. Its clearance was increased.

October 2. Reached 1800 rpm. Governor spring adjustment found wrong.

October 3. When at 1800 rpm, the governor-spindle bushing seized, causing a low-pressure "puff" in No. 1 bearing housing. Its clearance was increased.

October 5. Tested safety governor, and synchronized.

October 6. 40,000 kw carried.

October 7. Stopped for generator-fan inlet modifications, because one of the two axial-flow fans was inoperative. Bearing 6 and its journal were found scratched by foreign steel particles, and all bearings were examined and re-conditioned.

October 12. Resumed operation.

October 13. 50,000 kw maximum.

October 17. 80,000 kw maximum; started regular operation.

October 28–31. Turbine inlet valve sticking corrected.

December 29. In continuous service to this date of writing, normally at 80,000 kw from 6:00 a.m. to midnight except Sundays.

Turbine Comparisons

Lower turbine leaving losses characterize this latest unit, now operated three months. The 0.5 in. average annual exhaust pressure of turbines Nos. 1 and 2 was responsible for the use of almost double normal exhaust

Table 2 .

USE AND AVAILABILITY FACTORS

Unit	Period		Use Serv. Hr. / Period Hr.	Hourly-Output Av.Hrly.Output / Rated " "	Annual-Output Annual Output / " Rated "	Demand Demand Hr. / Period "	Demand-Avail. Service Hr. / Demand Hr.	Availability 100-Repair Hr. / Period Hr.
1	1948	Blr.	95.8	81.4	78	98.4	97.4	96.9
		Turb.	95.8	87.9	84.3	98.8	96.9	97.0
		Plt.	95.8	87.9	84.3	100	95.8	95.8
	1935*-48	Blr.	89.7	67.4	60.6	93.1	96.5	94.5
		Turb.	89.7	74.0	66.6	97.1	92.4	92.9
		Plt.	89.7	74.0	66.6	99.2	90.4	90.4
2	1948	Blr.	96.6	83.1	80.3	99.9	96.7	96.6
		Turb.	96.5	89.4	86.2	98.0	98.4	97.9
		Plt.	96.5	89.4	86.2	100	96.5	96.5
	1943*-48	Blr.	92.7	77.3	70.9	95.2	97.4	95.9
		Turb.	93.0	83.4	77.7	97.8	95.1	93.8
		Plt.	93.0	83.4	77.7	100	93	93
3	1948*	Blr.	90.4	76.1	68.8	90.4	100	100
		Turb.	90.4	86.8	78.5	100	90.4	90.4
		Plt.	90.4	86.8	78.5	100	90.4	90.4

*Nov. 22, Oct. 27, and Oct. 5 startings, resp.

blade area in the third unit. In fact, the double-flow low-pressure section of a 147,000-kw turbine for 1 in. average exhaust pressure was used for this 80,000-kw unit because of its 0.5 in. exhaust pressure. Also, the 36-in. blades with 1140 fps tip speed help improve economy at least 3 per cent, relative to units Nos. 1 and 2, because of lower leaving losses.

Another most important difference is 50 deg F higher superheat and reheat temperatures, thereby gaining about $1^1/_2$ per cent over the previous two units. Boiler pressure is the same, namely, 1390 psig design and 1335 psig operating. However, the extraction heaters are longer, affording lesser terminal temperature differences, and the condenser is of different design.

General design of this latest unit follows the essentially satisfactory plan of the previous two units and the flow diagrams are similar, the addition of a reheater-steam "dump" valve that bypasses 80 per cent of the 725 lb of full-load reheater-system steam directly to the condenser being the principal difference.

Heat Rate of No. 3 Unit

The figure of 10,000 Btu per net kwhr probably represents the ultimate average annual heat consumption of Port Washington No. 3, barring trouble. Its 9944 Btu per kwhr for December probably represents better than annual average performance, and there are reasons to believe that the 10,100 three months' average is about 1 per cent higher than the probable future average.

Port Washington No. 4 is scheduled for operation late this year and No. 5 in 1951. They will increase present 240,000 kw nominal station capacity to 400,000 kw.

Economy results of the three units during 1948 are shown graphically by the accompanying chart. The first month's heat consumption of unit No. 3, as plotted, does not include coal burned nor auxiliary energy used before starting the turbine, for they are not properly chargeable to normal monthly data. Including these one-time charges would increase the October figure to 10,437, which is better than the figure of No. 2 for the same month.

Lifetime and 1948 economy data for each unit are shown in Table 1. Use and availability data are recorded on the same basis in Table 2, which shows the recent 96 per cent availability previously mentioned. For 1948, turbine availability is slightly better than boiler availability, but over the years boiler availability has been almost two per cent points higher.

Reasons for every outage of all three units during 1948 are recorded in Table 3. Both semi-annual scheduled inspections of unit No. 1 were during week ends, taking advantage of bright Fridays, and unit No. 2 enjoyed only one full-week semi-annual inspection. Both turbines have operated approximately 25,000 hr since the last internal inspection.

Table 3 .

OPERATING PERIODS AND OUTAGES, 1948

Unit	Operating Period No.	Start	End	Hrs.	Outage Hrs.	Reason
1	74	*	4-1	2325.12	71.8	General inspection, blr. and turbine (scheduled).
	75	4-4	4-5	8.17	37.1	Furnace rear-water-wall tube failed at mud-drum joint (forced).
	76	4-6	4-16	233.2	128.1	Generator rotor lead failed (delayed forced outage).
	77	4-21	7-30	2403.9	33.4	P.W. 3 elect. connection. Furnace rear-water-wall tube repair (scheduled).
	78	8-1	8-1	13.77	30.9	Furnace rear-water-wall tube repair (forced).
	79	8-3	8-24	517.33	.48	Transm. line trouble; operating error (forced).
	80	8-24	10-21	1392.76	65.13	General inspection, blr. and turbine (scheduled).
	81	10-24	*	1522.8		
	(1948)	*	12-26	8417.07	366.93	
2	24	*	1-25	696.33	8.9	Leaking condenser tube (delayed forced outage).
	25	1-25	6-2	3107.97	.1	Erroneous automatic operation (forced outage).
	26	6-2	7-2	722.27	201.9	General inspection, blr. and turb. (scheduled outage).
	27	7-11	7-11	6.77	28.53	Leaking boiler tube, due to ash erosion (delayed forced outage).
	28	7-12	7-27	342.14	3.02	Erroneous H.P. heater testing (forced outage).
	29	7-27	7-27	1.6	.5	Erroneous automatic operation (forced outage).
	30	7-27	11-4	2408.34	68.68	General inspection, blr. and turb. (scheduled outage).
	31	11-7	*	1186.97		
	(1948)	*	12-26	8472.37	311.63	
3	1	10-5	10-7	45.95	121.13	Generator fan inlet changes. (Scheduled outage).
	2	10-12	10-28	386.35	68.29	Sticking of turbine inlet valves and power piston (delayed forced outage).
	3	10-31	*	1350.23		
	Totals	10-5	12-26	1782.53	189.42	

*Year starts 12-27-47 and ends 12-26-48

Heat Engines Discussed

THE Thirty-fifth Thomas Hawksley Lecture of the Institution of Mechanical Engineers (Great Britain) was delivered on November 19, by K. Baumann, chief mechanical engineer of Metropolitan-Vickers Electrical Co., Ltd. Using "Heat Engines" as his theme, Mr. Baumann reviewed the progress in the years between Captain H. R. Sankey's Thomas Hawksley Lecture of 1917 and the present, and indicated certain trends. Following is a brief digest of his remarks:

Steam Turbines

Not only has there been an increase in the individual capacities of steam turbines over this period, but their efficiencies have been raised much beyond those visualized thirty years ago by Sankey. In the advance of turbine outputs and speeds, the designers of the associated alternators have had their problems and in friendly rivalry neither side had cared to admit an inability to undertake an advance suggested by the other. Broadly speaking, the two sides have kept in step, and due to the progress in the technique of forging and metallurgical inspection, and to the general advance in electrical design and methods of ventilation, including hydrogen cooling, alternator designers have had no difficulty in meeting turbine designers' demands for single units.

The considerable advances in the thermal efficiency of power stations are due to the introduction of regenerative feedwater heating, to improvements in blade efficiencies, to the increases in steam pressures and temperatures, to increase in size and speed of units and to improvements in boilers and condensing plant.

The optimum improvement in thermal efficiency due to regenerative feed heating is shown in Fig. 1 for five-stage feed heating, for stop valve pressures from 200 psi to 1800 psi and a stop valve temperature of 800 F. This figure also shows the feed temperatures at which the optimum improvement is obtained. It will be noted that the greater improvement at higher pressures and temperatures has encouraged the adoption of these conditions. Thus, in Fig. 2 the improvement in thermal efficiency is shown by Curve *A* with feed heating, and by Curve *B* without feed heating. With feed heating there is a continuous improvement as the pressure increases, but without feed heating, a maximum is reached at about 1500 psi.

As far as steam turbines are concerned, it is estimated that the improvement in blade efficiency of turbines during these last thirty years is from 5 to 8 per cent, part of this improvement resulting from increased staging. There is also some improvement due to the increase in the capacity of turbines, but this is largely offset by the increase in pressures which in itself results in smaller blade heights in the high-pressure end and in an increase of gland and other leakage losses.

The increase in size of turbine units at 3000 rpm and higher has reduced the bulk of the generating unit and has had the effect of reducing the cost for a given capacity. With boilers, however, all the pressure bearing parts are affected by the increase in pressures. The superheater and steam piping are further influenced by the increase in temperature, and the bulk of the boiler cannot be reduced because heat-transmitting surfaces are still required to be of the same order.

Boilers

The introduction of pulverized-coal firing, which was one of the outstanding developments during these thirty years, has made possible great advances in boiler size. This, in turn, has been reflected in the tendency to use one boiler to one turbine, which results in a considerable simplification of the plant layout, but demands high availability of the boiler.

Reference should be made to the introduction of the pressure combustion boiler. An endeavor to reduce the bulk of the boiler plant by pressure combustion was proposed by Knudsen (1925) and later a more practical scheme was described by Stubbs (1927). Credit for having developed a satisfactory plant of this type, at least for burning oil, is due Brown, Boveri & Company, of Baden, Switzerland (Meyer, 1934). It is possible that future development of pressure combustion, such as is involved in the development of gas turbines, will give a further incentive to the development of pressure combustion boilers, particularly where space and weight are important, as in ships or underground stations.

With reference to marine practice, it must be recognized that, as output is generally small compared with that of land installations, high pressures are not justified to the same extent, as the advantages gained with higher steam conditions are bound to be smaller than in large land units. The trend of modern British marine practice is indicated in a recent article in which higher pressures and temperatures up to 1400 psig and 790 F with reheating are suggested for turbines of 13,000 shp, using the impulse type of turbines for the high pressure end.[1]

Gas Turbines

Sankey was unable to report any real progress in the gas turbine in 1917, although there had been much theorizing on this subject. Real advances with the gas turbine were made possible with the improvement of the compressor and with the development of heat-resisting steels. The first commercial gas turbine for public electricity supply was ordered in 1938, and installed as an emergency set in Neuchatel, Switzerland, in 1940. At present the largest gas turbine in operation is of 13,000 kw capacity, and the largest under construction is rated at 27,000 kw with an expected efficiency of 34 per cent.

The advent of the gas turbine has opened the door for various combinations of binary cycles. One example is the pressure combustion boiler, where the surplus power of the gas turbine driving the com-

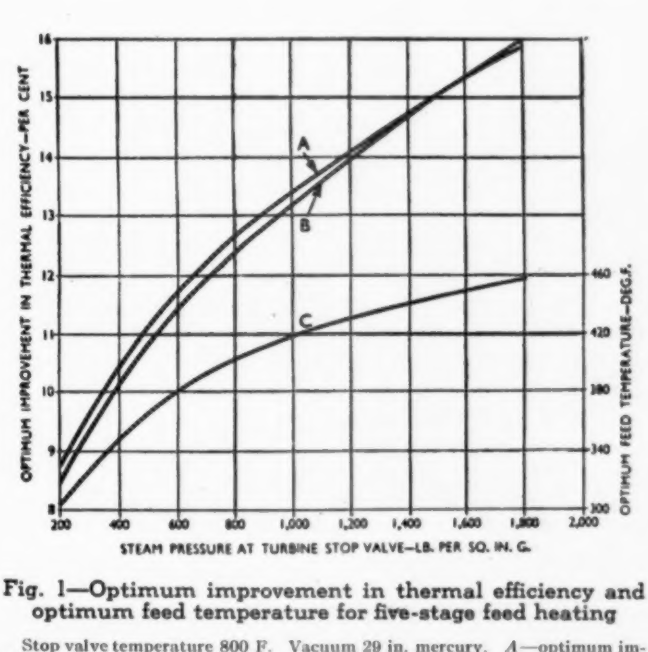


Fig. 1—Optimum improvement in thermal efficiency and optimum feed temperature for five-stage feed heating

Stop valve temperature 800 F. Vacuum 29 in. mercury. *A*—optimum improvement in thermal efficiency, including auxiliaries; *B*—optimum improvement in thermal efficiency excluding auxiliaries; *C*—optimum feed temperature.

[1] In American maritime practice the Bethlehem Steel Company has in successful operation eight ore carriers operating on the reheat cycle with initial steam conditions of 1450 psi, 750 F. (See COMBUSTION, November, 1945, p. 47.) There are also at least two American general cargo ships employing comparable steam conditions.—EDITOR

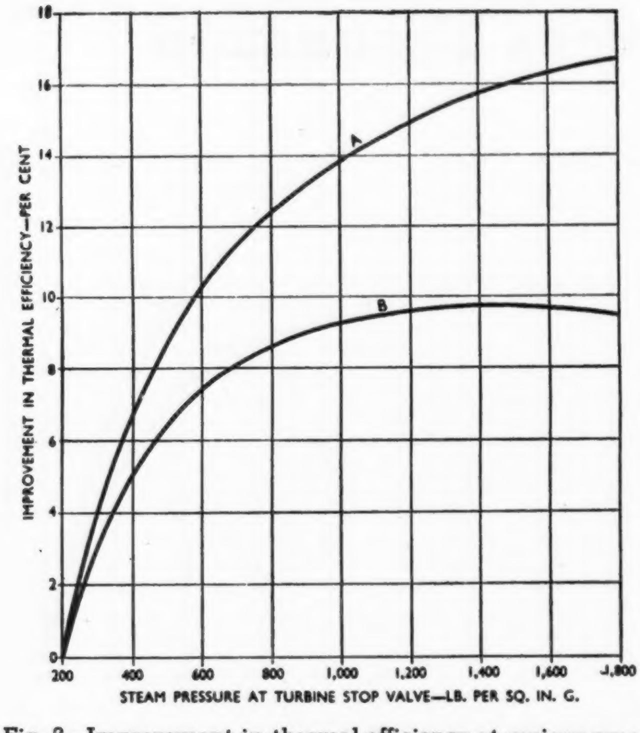


Fig. 2—Improvement in thermal efficiency at various pressures with five-stage feed heating and without feed heating

Vacuum 29 in. mercury. *A*—optimum improvement with five-stage feed heating; *B*—improvement without feed heating.

pressor is utilized. Various combinations of gas turbines, boilers with pressure combustion, and steam turbines suggest themselves and numerous patents have been taken out, but it is too early to say whether any are worthy of serious consideration.

In choosing a prime mover, Mr. Baumann cautioned that reliability must always receive due consideration. Capital costs are also an important factor, and they may be reduced by paying due attention to standardization and to the application of methods of mass production. In the advance of improvement in heat engine efficiency, competition between groups of engineers throughout the world has been a dominant factor. However, with continued research, this competition need not interfere with the development of standardization and mass manufacturing equipment. Thermal economy and financial economy both have important rôles in prime movers of the future.

Addition to Cliffside Station

On December 10, a formal celebration was held at Shelby, N. C., to commemorate the second addition to the Cliffside steam-electric plant of the Duke Power Company. This station, located at Cliffside, in the foothills of the Piedmont Carolinas, was first placed in service in July 1940, with a capacity of 80,000 kw in two units. As a part of the Company's expansion program to meet post-war demands, construction was begun in 1946 to provide two additional units of 65,000 kw each, thus increasing the total capacity to 210,000 kw. The first of these went into service last May and the second late this past fall.

Each of the new turbine-generators is supplied with steam at 1285 psi, 950 F by a 620,000-lb per hr C. E. steam generating unit tangentially fired with pulverized coal. The overall thermal efficiency of the station is said to be around 32 per cent.

Charles E. Wilson, president of General Electric Company, addressing the gathering at Shelby. Next to him at the table is Senator Hoey; then J. V. Santry, president of Combustion Engineering-Superheater, Inc.; and E. E. Williams, general superintendent of steam plants, Duke Power Company.

Fields for Engineering Graduates

The very great increase in enrollment of engineering students in colleges has caused concern in some circles as to the ability of industry to absorb the yearly output of engineering graduates. In an attempt to answer this question, Dr. A. A. Potter, Dean of Engineering at Purdue University, and F. L. Cason, Coordinator of Placement, presented some interesting observations at one of the luncheon meetings during the A.S.M.E. Annual Meeting.

It was pointed out that many new fields of employment for engineering graduates are now apparent, in addition to those commonly associated with engineers. These include financial institutions, insurance companies, the food industries, drug manufacturers, large department stores, real estate firms, etc. An increasing demand for engineering graduates is also found in government agencies, particularly in the Navy, a recent study having indicated that the U. S. Navy normally should have available at least 5 per cent of the country's present output of engineering college graduates. The Army and Air Corps will need more engineers, as will also numerous government laboratories.

Furthermore, water supply, waste disposal problems and smoke elimination are bound to require more engineers as our population grows.

In conclusion, Dr. Potter expressed the opinion that the foregoing opportunities, superimposed upon present fields for engineering talent, should insure adequate employment for those with engineering education, provided the graduate has adaptability to utilize the engineering type of approach in tackling problems.

Power in New England

A report has just been issued by the Power Survey Committee of the New England Council covering a comprehensive investigation of power supply and demand and related economic factors in that section of the country. The survey was directed by William Uhl, president of Charles T. Main, Inc., consulting engineers, Boston, Mass., assisted by a representative committee.

While the population of New England has increased about 20 per cent since 1920, the output of electric utilities has increased over 400 per cent. However, due to improvement in load factor, multiple-shift industrial operation, more efficient use of reserve capacities, and the development of extensive interconnected transmission facilities, this increase in electrical output has been accomplished with but slightly more than a 200 per cent increase in generating capacity.

Interconnected companies provide each other with material assistance in times of emergencies, while at the same time less margin of reserve is required than for independent systems. Interconnection also permits taking advantage of diversity in peak loads. The interconnected system of New England, exclusive of Maine, functions through a voluntary committee which endeavors to insure the best planning and operation of all the facilities in the area for maximum economy and protection.

For the next ten years the requirements for expansion of the New England generating capacity are foreseen as about 1,100,000 kw. With the exception of Maine, most of the new generating units will use fuel.

Consideration is also given by the report to the proposed St. Lawrence seaway and power project, and the conclusion is reached that, allowing for the growing power demand in upper New York State alone, New England should not rely upon the St. Lawrence as a future source of power.

The study shows that, except in those industries using process steam, manufacturing establishments are depending more and more upon utilities for their power supplies.

Some interesting comments are made concerning the relation of power costs to total manufacturing costs, in which connection the following statement is made:

"It is fallacious to cite the cost of power as a major cause of industry's leaving New England to locate in areas where cheap power is available. In most industries the cost of power is a small percentage of the total cost of manufacturing in comparison to wages and material costs. Wide variations in the cost of power would have little effect on the position of industry in competing for markets, compared to the effects of variations in wage rates, efficiency of labor, and cost of materials in different sections of the country."

To cite a few industries, the ratio of power cost to product value (based on the selling value of the manufactured product at the plant), in per cent, ranges from 0.2 for tobacco manufacture, 0.4 for apparel

made from fabrics, 0.6 for leather and leather products, 0.8 for printing, 0.9 for machinery (except electrical which is 1.1), 1.1 for food products, iron and steel products 2.0, textile mill products 2.3, and paper and allied products 3.0. The average of all industries for New England is given as 1.67.

The report should effectively serve the purpose of helping to develop an informed public opinion concerning the importance of power in an industrial economy, as well as to point the way to economically sound policies and enlightened action on the part of both private management and agencies of the Government.

The complete survey, covering 68 pages, with numerous charts, maps, etc., is obtainable from The New England Council, Statler Building, Boston 16, Mass., at a cost of one dollar.

Moisture Terminology

With reference to the letter from Max Hecht in the December issue, commenting on moisture terminology, I would like to offer the following:

Mr. Hecht referred to the conductivity of a condensed sample of steam as an indication of the amount of boiler water included with the steam. On dozens of occasions I have found the conductivity of condensed steam samples to indicate a dissolved solids concentration from 50 to 200 per cent of that existing in the boiler water. All of these samples were taken well above the water line in the steam drums of the boilers. It is hardly possible that the amount of water present could be expressed by the ratio of the dissolved solids between the steam and the boiler water as indicated by this conductivity reading. If such a ratio were used how can one think of 200 per cent moisture in the steam? Similarly, if we assume sampling error we could not possibly obtain a concentration of more than 115 per cent of the boiler water concentration if the water sample included nothing but the concentrated boiler water as yet unmixed with incoming feedwater. For these reasons there should be a re-examination made of the significance of conductivity readings on condensed steam samples, as an indication of the amount of moisture present. I have personally come to the conclusion that there is no relation between the amount of moisture in steam and its conductivity.

In another part of Mr. Hecht's letter he stated that the evaporation of a sample of condensed steam would give the dissolved solids concentration. This is undoubtedly a case where Mr. Hecht misspoke himself because it is perfectly obvious that total solids including both suspended and dissolved solids would constitute the residue remaining after the evaporation of a condensed sample of steam. Only in the complete absence of suspended matter would the residue indicate dissolved solids.

It seems that in general we do not keep in mind the fact that a conductivity measurement is not an indication of the total solids present in the condensed sample of steam. Troublesome substances may be present in the suspended and insoluble form and therefore not appear at all in the

conductivity measurement. Such substance may constitute the major part of the adherent deposits on turbine blades. It is acknowledged that we do not yet know how to sample steam so that a representative portion of the soluble and insoluble materials carried with it are included with the sample, but certain samples taken by the writer have shown the amount of insoluble material to vary from about one-fifth of the soluble material to over twice as much as the soluble material. It is well to keep this in mind because many people, applying a factor to a conductivity reading, consider that they have made a measurement of the amount of solids in the steam, and this is not so.

It seems to me that a discussion I had with Mr. F. W. Dean thirty years ago had the same subject as your editorial in the October issue, upon which Mr. Hecht commented. Mr. Dean at that time insisted that it was perfectly proper to have a quality greater than one to indicate the presence of superheat. It seems to me you have started something which should be finished because the thinking on this subject is neither exact nor clear.

A. R. MUMFORD

Combustion Engineering and Superheater Merge

Merger of two well-known power equipment manufacturers—Combustion Engineering Company, Inc., and The Superheater Company—was consummated on December 22 by approval of the stockholders of both companies. It became effective on December 31, 1948, under the new name of Combustion Engineering-Superheater, Inc.

The original Combustion organization was founded in 1914, its products including Type E, Type H and Coxe stokers. Subsequently it absorbed other manufacturers of fuel-burning equipment and several boiler companies, the latter including the manufacturers of Heine, Walsh-Weidner, Casey-Hedges and Ladd boilers. Two of these companies started in the field in 1884, and several others were organized prior to 1900.

The Superheater Company was organized in 1910 as the Locomotive Superheater Company, designing and building superheaters for locomotive boilers. Later it expanded its line of products for locomotives and developed superheaters and other equipment for power plant boilers as well as marine and oil-country boilers.

Following World War I, both Combustion and Superheater were identified with major new developments in steam generation. Combustion was chiefly responsibe for the commercial development of pulverized coal firing of boilers, water-cooled furnaces and completely integrated designs of steam-generating units. Superheater pioneered in the development of superheater designs for higher steam pressures and temperatures. Both companies were identified with many of the installations which in the period from 1920 on set new standards of practice and performance.

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Domestic manufacturing plants owned by the two companies occupy some 115 acres and are located at Monongahela, Pa.; Chattanooga, Tenn.; Chicago; East Chicago, Ind.; and St. Louis. Plants operated by subsidiary companies are located in Canada, England and France.

The companies do business outside the U. S. A. through representatives in the principal cities of Latin America and the Orient and through the following subsidiaries: The Superheater Company, Ltd., Montreal; Combustion Engineering Corporation, Ltd., Montreal; Combustion Engineering de Mexico, S. A.; Combustion Engineering Limitada, Brazil; The Superheater Company, Ltd., London; The Superheater Company, Pty., Ltd., Sydney; Compagnie des Surchauffeurs, Paris; and Stein et Roubaix, Paris.

The two companies became affiliated in 1933, and since then it has become increasingly evident that important advantages could be obtained by merging all operations under a single management. The new company will continue the worldwide activities of the present companies in the manufacture and installation of steam-generating and associated products, and such equipment as chemical recovery units for pulp mills; flash drying systems for a wide variety of materials; sewage incineration systems; mills for pulverizing products of the process industries generally; soil pipe and castings; domestic water heaters; and range boilers.

Officers of the new company are: Frederic A. Schaff, Chairman of the Board and Vice Chairman of the Executive Committee; Samuel G. Allen, Chairman of the Executive Committee; Joseph V. Santry, President; Martens H. Isenberg, Executive Vice President; Harold H. Berry, Vice President in Charge of Finance. Vice Presidents: Wilbur H. Armacost, George D. Ellis, Amaziah J. Moses, John S. Skelly, Otto W. Strauss, Donald S. Walker, Albert C. Weigel, Arthur Williams. Secretary and Assistant Treasurer—Irving B. Swigart. Assistant Secretaries—Thomas F. Morris and Francis J. Dolan. Assistants to Chairman—Thomas F. Morris and Frank R. Fitzpatrick.

Refinery Capacity Reaches New High

Petroleum refineries of the United States had record-breaking rated operating capacities nearly a half-million barrels daily greater than a year previous according to the latest annual survey of petroleum refineries and cracking plants by the Bureau of Mines.

Texas, with 80 refineries and one under construction, led other states in the number of installations and also was the leading state in the crude-oil throughput capacity with 1,722,000 barrels per day. California's 61 refineries had a rated capacity of 1,093,700 barrels per day: Pennsylvania's 18 refineries had a potential capacity of 446,150 barrels per day; and Louisiana's 18 refineries, 433,900 barrels daily.

New Catalogs and Bulletins

Any of these may be secured by writing Combustion Publishing Company, 200 Madison Avenue, New York 16, N. Y.

Boiler Protective Coating

The Dampney Company of America has issued an 8-page booklet dealing with Apexior No. 1, a protective surfacing material for boilers and for power and processing equipment in similar wet-heat surface. It also provides application data, with information on special Dampney equipment for the internal coating of boiler, water-wall and economizer tubes.

Continuous Material Weighing

Builders-Providence, Inc. has just released a 16-page bulletin describing its new "Conveyflow Meter" for continuously weighing and totalizing the flow of dry materials. Included in the bulletin are diagrams showing space requirements for various models, as well as descriptions of component parts and methods of operation.

Bonnet Valves

A new catalog describing all types of cast-steel pressure-seal bonnet valves has been issued by Edward Valves, Inc. These valves are of a new flow design, in stop, non-return and check types, with chromium-molybdenum steel bodies and welding ends for services ranging between 900 and 2500 psi at 1000 F. Of interest to design engineers is the inclusion of charts and instructions for the correlation of valve size and pressure drop.

Heat-Exchangers

An informative 32-page bulletin on tubular heat-exchangers has recently been published by The Griscom-Russell Co. Helpful features of the bulletin are tables of the characteristics of tubing, the thermal resistance of tubes and pipes of many different metals and alloys, and the specific gravity and pounds per gallon corresponding to degrees Baumé and degrees API; also a chart of specific heats of mid-continent crude oil and charts for solving the mean temperature difference formula. Illustrations and photographs of complete heat-exchanger units, together with modern installations, are shown.

Oil Burner Assembly

Peabody Engineering Corp. has just released Bulletin 400 which describes an automatic wide-range oil-burning system assembled on one base. The unit, which is designed for burning Bunker "C" or lighter fuel oils and is assembled ready for service connections, is illustrated by several photographs.

BOOKS

1—Elementary Heat Power

By H. L. Solberg, O. C. Cremer and A. R. Spalding

480 pages $8\frac{1}{2} \times 5\frac{1}{2}$ Price $4.75

The authors prepared this text with a view to providing an understanding of heat-power equipment and a background for its testing, regardless of whether the student follows with a course in thermodynamics. In fact, the aim is thus to stimulate student interest in thermodynamics through a prior, more concrete knowledge of its applications. Emphasis is placed on fuels as sources of energy, the functioning of equipment and its performance.

The sequence of the contents includes matter and energy, fuels and combustion, internal-combustion engines, fuel-burning equipment, steam generation, steam power-plant cycles, steam engines, steam-turbines, pumps, fans, blowers, compressors, feedwater heaters, condensers, gas turbines and mechanical refrigeration.

Numerous problems are included and abridged steam tables are appended.

2—Specifications for Steel Piping Materials

307 pages Price $3.00

In addition to all A.S.T.M. specifications covering steel piping and tubing, the December 1946 compilation of A.S.T.M. Specifications for Steel Piping Materials includes requirements on a number of other materials which are used in piping installations, such as castings, forgings, bolting materials and nuts.

The book includes 14 specifications covering various types of pipe ranging from ordinary carbon pipe for a variety of uses to high-alloyed steels for high-temperature and high-pressure service. Thirteen specifications cover various types of boiler, superheater and miscellaneous tubes, including four standards on stainless tubing. Three specifications cover still tubes, and a similar number pertain to heat-exchanger and condenser tubes. Five standards cover castings used in pipe installations, including valves, flanges and fittings, and there are four specifications covering forgings and welding fittings. Three standards cover carbon and alloy-steel bolting.

3—Steam and Gas Engineering

By Butterfield, Jennings and Luce

588 pages 6×9 Price $6.00

This is the fourth edition of a book well known to the field of power engineering, particularly from the educational angle. Much of the text of the last edition has been rewritten and enlarged, particularly that dealing with thermodynamics, steam generation, turbine-generators and refrigeration. Also, in view of the recent increased importance of the gas turbine, more space has been devoted to this subject, together with the turbojet and the turbo-supercharger. Up-to-date illustrations have been substituted in many cases for those of the previous edition, and the tables and charts have been amplified. Like most other books intended for classroom reference, numerous selected examples with their solutions are included. Without attempting to enumerate the twenty-four chapters, it may be said briefly that they encompass the range of heat-power engineering as taught in most technical schools.

Aside from being a well balanced textbook, the volume should serve as a useful reference or refresher for practicing engineers.

4—Hydraulic Measurements Second Edition

By Herbert Addison

327 pages $5\frac{1}{2} \times 8\frac{1}{2}$ Price $5.00

This is a practical treatise confined to the measurement of liquids and requiring only an elementary knowledge of hydraulic principles, such as is possessed by most mechanical engineers.

In general, types of instruments and their functions, rather than makes of instruments, are dealt with; and because of contradictory opinions on methods of fluid measurement, the advantages and limitations of each are discussed. An idea of the coverage may be had from the chapter titles which are: direct measurement of depth, head and pressure; indirect indication and transmission of pressure, head or depth readings; installation and operation of pressure and depth gages; measurement of weight and volume; measurement of velocity; measurement of discharge by free-flow apparatus; measurement of discharge in closed pipes and conduits; measurement of discharge in open streams; and indicating, recording and integrating instruments for flow-measuring installations.

The practicability of the book is enhanced by many helpful illustrations showing how to apply the various methods and instruments.

5—Pressure Vessels for Industry

By Harry M. Spring, Jr.

259 pages $5\frac{1}{2} \times 8$ Price $3.50

Directed primarily to plant engineers responsible for the operation of pressure vessels, the text covers such vessels as are used for compressed-air systems, steam and hot-water services, pulp and paper mill processes, the rubber industry, textile mills, selected chemical industries and various specialized services. This is supplemented by chapters on design and stress calculations, pressure-vessel appliances, defects, repairs and the prevention of hazards. An appendix contains useful charts and conversion tables as well as a tabulation of state regulations for pressure vessels. Steam boiler rules are not included.

6—Technical Dictionary English-French

By Francis Cusset

590 pages $6\frac{1}{2} \times 5$ Price $5.00

Many technical fields are covered in this book and it should meet the needs of translators, students and technical men who have occasion to read texts in the other of these languages. Furthermore, at a time when the French are negotiating for the purchase of American equipment to replace war-devastated plants in France, such a dictionary will be found helpful to those charged with the preparation of specifications.

An appendix contains a number of useful English-metric conversion tables.